GRASS CREEK

OIL AND GAS LEASING ENVIRONMENTAL ASSESSMENT RECORD

AU OF LAND MANAGEMENT
AND DISTRICT, WYOMING

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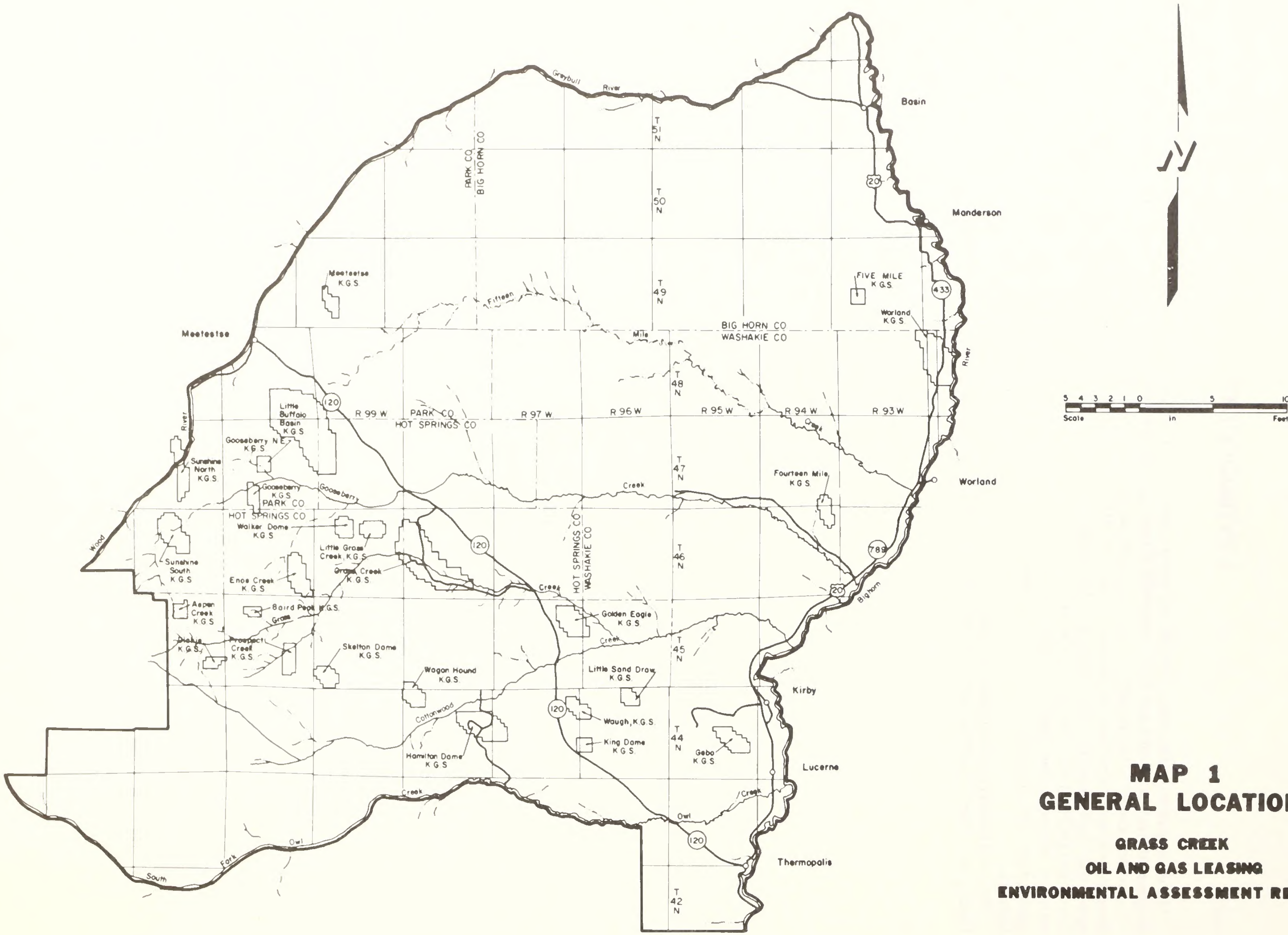


MAP 1
GENERAL LOCATION

GRASS CREEK
OIL AND GAS LEASING
ENVIRONMENTAL ASSESSMENT RECORD

II. DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES

The proposed action considered in this analysis is:

1) To continue to allow preliminary exploration for oil and gas by the authority and instructions contained in Wyoming BLM Manual Supplement 3045 — Surface Management Requirements for Geophysical Exploration (see 3045 Manual Supplement, Worland district files).
2) To continue to administer current oil and gas leases and issue new oil and gas leases in the area by the authority and the instructions in Wyoming State Office Manual Supplement 3109 — Surface Management Requirements for Oil and Gas Operations. (See 3109 Manual Supplement, Worland district files.)

Area of Consideration

The study area includes some 1.5 million acres of federal, state and private land. (See study area Map 1.) It is bounded on the east by the Big Horn River, on the north by the Wood and Greybull Rivers, on the west by Shoshone National Forest, and on the south by Wind River Indian Reservation.

Table 1 lists the acreage owned by private individuals and state and federal government.

TABLE 1
Acreage by Ownership[1]

Ownership	Acres	Percent of Total
Surface:		
Federal	979,614	65.5
State	105,627	7.1
Private	411,205	27.4
Total	1,496,446	100.0
Subsurface:		
Federal minerals, federal surface	979,614	65.5
Federal minerals, non-federal surface	206,533	13.8
(total federal minerals)	1,186,147	79.3
Non-federal minerals and surface	310,299	20.7
Total	1,496,446	100.0

[1]Compiled from 1976 BLM master title plats by Wyoming State Office.

Assumptions and Guidelines

This assessment considers the environmental impacts associated with possible exploration, development, production, and abandonment of oil and gas operations on any land under federal lease. Thus, the assumption is made that any leasing action can result in oil and gas production, although historically only a small percentage of leases issued have gone into the production stage.

Activity Levels

Estimates of oil and gas activity over the next ten years will be used. Ten years is assumed since use of a longer period in this study would lead to excessive speculation. Use of a shorter period would not allow sufficient scope for meaningful analysis. Too, it is anticipated that the oil and gas leasing policy will be reassessed after ten years.

Technology

For purposes of this analysis it is assumed that the technology of oil and gas production will not change significantly. This assumption may not be objectively valid, but it is impossible to guess what direction improving technology may take.

Supply and Demand

Many factors significantly affect oil and gas prospects in the Grass Creek area. For instance, domestic demand may decrease due to development of a new energy source, or increase because of export restrictions imposed by foreign oil suppliers. A new, major oil field could be discovered in Grass Creek, increasing activity. Since there is no way to accurately predict these changes, it is assumed that supply, demand, and production activity will follow current trends, and that major new fields will not be discovered.

Preliminary Exploration

Preliminary exploration is expected to increase at a rate of about five percent a year, with most of it in the deep formations. Exploratory drilling will also increase at a rate of about five percent a year, in response to an increasing demand for petroleum products. Drilling will be in the deep formations and on the fringes of existing fields. De-

velopment is expected to continue at about the current level as existing fields are further exploited. Production has decreased at about five percent annually over the last several years, as reserves have been depleted, and we anticipate that this trend will continue for the next ten years. Abandonments are expected to increase at a rate of about five percent a year as older fields are depleted.

Land for Producing Facilities

Land-use intensity decreases as well spacing increases. The land use by all facilities in a developed field may range from more than 20 acres per square mile, with a 20-acre-per-well spacing, to about 2 acres per square mile with 640-acre-per-well spacing. These acreages are adequate for most field operations. The amount of land actually used may be greater in some areas and less in others. Most spacing patterns for oil wells on federal leases require a minimum of 40 acres per well.

Land use in gas fields is usually less than in oil fields because gas production usually does not require storage on the lease. Most patterns for production of gas on federal leases require spacing of 160, 320, or 640 acres per well.

Employment

The number of people required to operate a field varies with production and the number of leaseholds in the field. If the wells flow without pumping, one employee in a large, modern field can control production of about 25 wells. When wells are pumped, one employee in a large modern field can control production on 10 to 20 wells. If oil storage tanks are manually gauged and sampled, one employee can service approximately 25 tanks. If automatic gauging and sampling devices have been installed, one person can service the equivalent of 100 to 150 tanks. In a large, modern field one five-man maintenance crew can service up to 50 wells.

If the field contains many small, non-unitized leaseholds, more people will be needed to control production and maintain facilities.

Program Status

The oil and gas industry in Wyoming is important nationally. The state ranks fifth in crude oil production, with 4.5 percent of the nation's total, and seventh in natural gas production, producing 1.5 percent of the total. Activity in Wyoming is influenced by national trends and has thus grown with our increased need for petroleum products. Activity fluctuates, but has generally increased over the years.

Drilling activity in the state reached a 14-year high in 1976 when 1,001 wells were drilled to a total of 6.8 million feet, or an average depth of 6,775 feet. On average, 107 drilling rigs were operating in the state at a time that year. Of the 1,001 wells drilled, 428 were completed as oil or oil and gas wells, 40 came in with gas, and 533 were dry.

Wyoming crude oil production in 1976 totalled some 143.1 million barrels, while natural gas production was 330.2 billion cubic feet. There were 9,952 producing wells in the state, of which 2,892 produced oil, 100 yielded natural gas, and 6,960 yielded both oil and gas.

Estimated recoverable reserves in the state have steadily declined in recent years as production increased.

There were almost no free-flowing wells in the state, as nearly all require pumping to force the petroleum to the surface.

The Grass Creek study area had a total of 739 producing wells in 1975. These wells produced 17.4 million barrels of oil and 9.2 billion cubic feet of gas in 1976. Total cumulative production in this area is 403.3 million barrels of oil and 489.1 billion cubic feet of natural gas. Production first began in the area in 1914. The most recent new field discovery was at Aspen Creek in 1974.

Production by KGS is shown in Appendix 1.

Major oil and gas producing formations in the area are the Tensleep, Phosphoria, Dinwoody, and Frontier. Other producing formations are the Muddy sandstone member of the Thermopolis shale, the Crow Mountain sandstone and the Alcova member of the Chugwater Formation, and the Darwin sandstone of the Amsden Formation. The Phosphoria and Dinwoody Formations are known also as the Embar Group.

Lessees pay royalties to the Department of the Interior on oil and gas produced. In 1974, royalties from production on federal leases in Wyoming were $69 million. Table 2 shows the distribution of these royalties.

TABLE 2
Distribution of Federal Oil and Gas Royalties in Wyoming 1974[1]

	Percent	Millions of Dollars
Treasurer of the United States	10.0	6.9
Bureau of Reclamation	52.5	36.2
State General School Fund	18.8	13.0
University of Wyoming	3.4	2.3
State Highway Fund	13.1	9.0
State Highway Fund (county roads)	1.1	0.8
County of Lease	1.1	0.8
Total	100.0	69.0

[1]Effective February 1977, distribution of royalties back to the State of Wyoming went from 37.5% to 50% and minimum rental rate rose from $.50 to $1.00/ac.

Phases of the Proposed Action

Oil and gas operations progress through five phases: preliminary exploration, exploratory drilling, development, production, and abandonment. (See Figure 1.) Leases are obtained either before the first phase or between the first and second phases. If the area of interest is un-

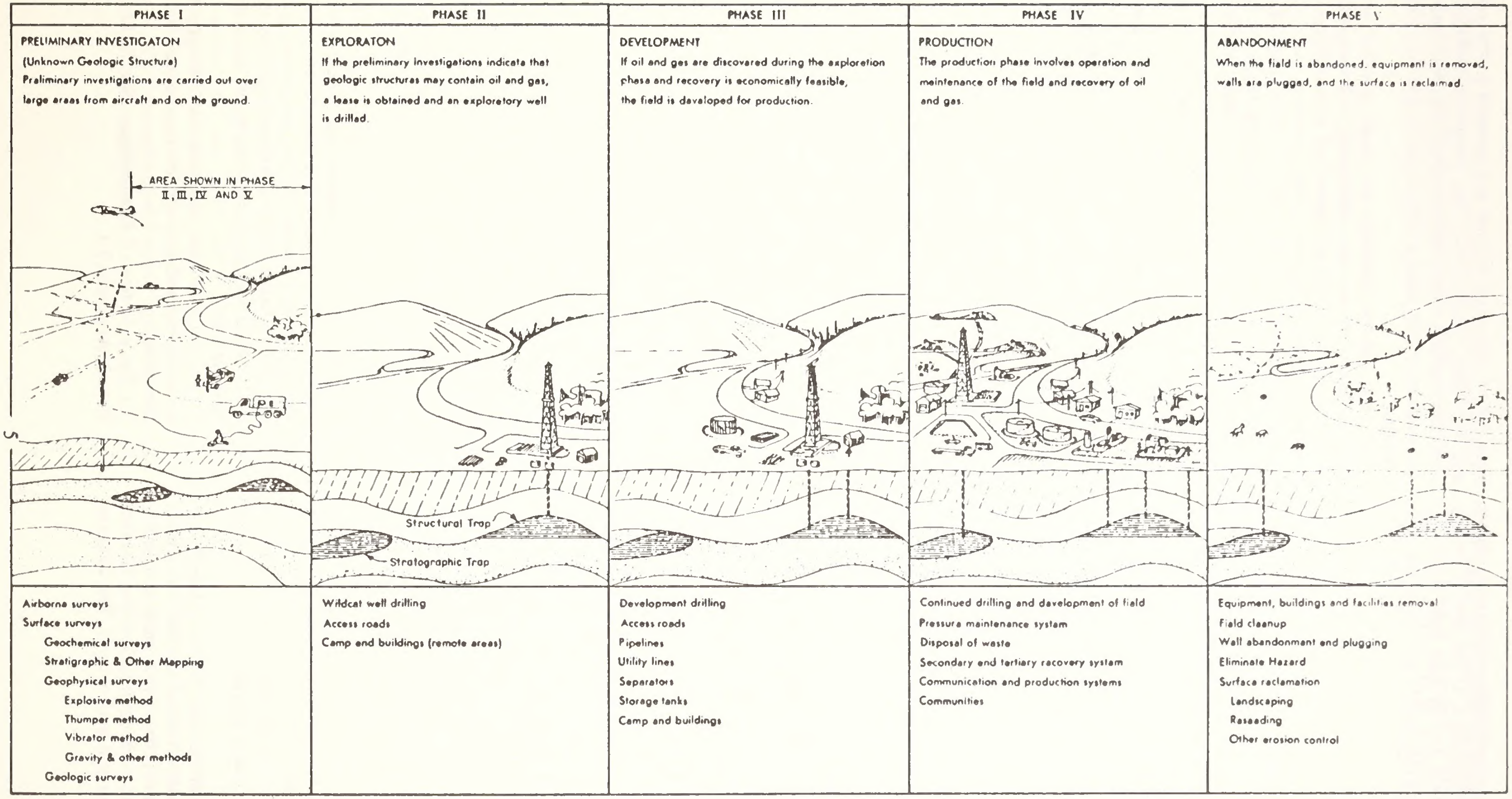


FIGURE I SEQUENCE OF OPERATIONS IN AN OIL AND GAS FIELD 1/

1/ U. S. Department of Interior, Bureau of Land Management, 1972. Preliminary draft, Upland Oil & Gas Leasing Programmatic Environmental Impact Statement.

leased, a company planning exploration will usually obtain leases before beginning exploration. If the area is already under lease, a company will usually wait until after preliminary exploration before attempting to acquire the lease from the lessee.

Preliminary Exploration

History In the early history of the industry, the presence of surface oil indicated many prime areas. However, today the presence of oil may be revealed by indications of likely oil-and-gas bearing structures or "traps" underground. This can often be determined by a general knowledge of the geology of the area, from which conclusions as to subsurface structures can be drawn. This is known as geological prospecting.

The other type of prospecting, geophysical, is accomplished by measurement and interpretation of the physical structure of the underground area.

Methods Where the surface geology of an area is easy to map, it is often possible to predict where oil might gather, and anticlines, faults, or porous formations are sometimes located using geological prospecting. This type of exploration can usually be performed with little surface damage, requiring perhaps some off-road vehicle travel to cover the area.

Subsurface geology is not always accurately indicated by surface outcroppings. In such cases geophysical prospecting is used. Three subsurface characteristics are usually measured by geophysical methods: gravitational field, magnetic field, and seismic characteristics.

Gravitational prospecting detects variations in gravitational attraction caused by differences in the density of various types of rock. There is normally very little surface disturbance.

Magnetic prospecting is often used to supplement gravitational work, or may even replace it, since magnetic methods have proven more successful. Magnetic methods reveal upwarped structures (likely to yield oil and gas) because such structures show a strong magnetic response. Magnetic prospecting generally results in slight surface disturbance.

Seismic prospecting is the most popular of the geophysical methods. It seems to give the most reliable results. Shock waves are initiated using a thumper or vibrator on the surface, or explosives in the bedrock. Sensors may also be placed in the bedrock. Many such operations require exposing or drilling into the rock.

In the explosive method, shot holes are drilled to a depth of 50 to 200 feet. One to fifty holes are drilled per mile. The holes are loaded with 5 to 50 pounds of explosives and detonated. The same hole may be reloaded and shot several times to find the depth and charge returning the best signal.

The thumper and vibrator methods pound or vibrate the earth to create a shock wave. Vibrator methods are widely used and are replacing the drill and shoot method. Usually four large trucks are used, each equipped with a vibrator mounted between the front and back wheels. The vibrator pads (about four-foot square) are lowered to the ground and vibrators on all trucks are triggered electronically from the recorder truck. Information is recorded and then the trucks move forward a short distance and the process is repeated.

All three seismic methods use small one-half to five pound shock wave detectors, in contact with the ground at spaced intervals. These are connected to a recorder truck that receives and records the reflected waves.

The seismic sensors and energy source are located along lines on a one- to two-mile grid. Existing roads are used if possible. If permitted by the surface owner, lines may be cleared of vegetation and loose rock to improve access for the trucks. Each mile of line cleared to a width of 8-14 feet represents disturbance of an acre of land.

In remote areas where there is little known subsurface data, a series of short seismic lines may be required to determine the regional dip and strike of subsurface formations. After this, seismic lines will be aligned with these formations to make seismic interpretation more accurate. Although alignment may be fairly critical, spacing of the lines can often be changed up to a quarter of a mile on a one-mile grid, before the results will affect the investigation program.

A typical seismic operation may use 10 to 15 men operating five to seven trucks. Under normal conditions, three to five miles of line can be surveyed each day using the explosive method; five to ten miles are about average for a vibrator crew. The crews often work 70 to 80 hours a week in good weather.

Operator's Requirements Development of an oil and gas property is an expensive proposition. Therefore, before exploratory drilling is undertaken, geophysical exploration of the area is conducted. In Wyoming, geophysical operators are required to follow the following procedures for each exploration program:

1) To file a Notice of Intent to Conduct Oil and Gas Exploration Operations. (See BLM Form 3040-1, Appendix 2.) The notice must include maps showing the location of the line(s) and all necessary access routes before operations begin. The map should be a minimum scale of one-half inch equals one mile.
2) To be bonded.
3) To notify the District Manager before he enters onto public lands.
4) To obtain the District Manager's written approval for bulldozer or other dirt work. (See Form WSO 3045-4, Appendix 2.)
5) To notify the District Manager in writing of any changes in the original nature and secure written approval for the changes before proceeding.
6) To comply with the instructions and orders given by the District Manager at the pre-work conference and during field investigations. (See Form WSO 3045-4, Appendix 2.)
7) To notify the District Manager that their operations are complete and they are leaving the land listed on the notice.
8) To file a Notice of Completion. (See BLM Form 3045-2, Appendix 2.)

If all requirements have been met and there is no significant surface disturbance, the operator's bond is released and that is the end of the action.

Description of the Leasing Process

While the leasing action itself is an administrative activity without direct impact on the environment, familiarity with the process is necessary to understand operations which do have on-the-ground impact.

Oil and gas leases fall into two categories — competitive and non-competitive. Competitive leases are issued in areas known to produce oil and gas (Known Geological Structures). Non-competitive leases are for land outside Known Geological Structures (KGS) and are available as a result either of open-land offers or simultaneous filing for lands previously leased.

The public may request that KGS land be offered for competitive leasing. The USGS prepares a report as to KGS status, recommends whether competitive leasing is in the public interest, and nominates tracts to be grouped in lease parcels.

If leasing is recommended, land nominated by the public is combined with USGS nominations (in active KGS areas), the BLM district office is consulted concerning conflicts with land-use planning, and a competitive lease sale is scheduled.

The BLM conducts the sale. Sealed bids are accepted for each tract. After bids are opened, BLM and Geological Survey representatives determine their adequacy. For each bid accepted, a lease is issued, and the lessee is required to pay a cash bonus. Competitive leases are for five years.

For non-competitive leases, action is initiated when an applicant applies for an unleased parcel in a non-KGS area. If the land is available, the BLM district office responds with any recommendations and, upon approval, the lease is issued to the applicant without competition or drawing.

In "simultaneous filing," previously-leased parcels in non-KGS areas are listed monthly as they become available following termination of the old leases. The BLM district office makes recommendations as to land-use suitability. Once a list is approved and advertized, all applications received during the filing period are considered to have been filed simultaneously. An applicant may file only one application per tract. A lottery-type drawing is held and one application is drawn for each tract.

If there are no applications for the tract, it is available to the first applicant subsequent to the drawing. Non-competitive leases are issued for ten years.

All leases require rent payment in advance plus royalties based on production. Rent on non-competitive leases is $1 an acre a year. Upon production of oil and gas, the royalty is 12.5 percent of value. Rent and royalty on competitive leases are prescribed in the lease terms.

Prior to issuance of either competitive or a non-competitive lease, the lessee must post a surety bond to ensure compliance with lease stupulations.

Wyoming Procedures for Lease Issuance Before an oil and gas lease is issued, it is sent to the Worland district office for review. They review the proposal and recommend special stipulations over and above those contained on the lease form and the Open End Stipulation. (See BLM Form 3109-5, Appendix 2.)

Special stipulations are designed to accommodate circumstances specific to the lands at issue. The BLM and the Conservation Division of U.S. Geological Survey are required to concur with all stipulations included in an oil and gas lease. Ten stipulations have been developed for the state. (See Appendix 2.)

These stipulations cover most of the situations within the state. If they do not cover a specific problem, new stipulations can be developed. The only requirement is that the district obtain the local USGS district engineer's concurrence.

The district is aided in this task by its retrieval system overlay. (See Map 2.) The overlay has areas drawn on them and a list of the stipulations to be added to leases that fall within the area. This helps develop consistency, and the information is readily available.

The district has designated a no-leasing area in the Grass Creek study area which is the South Fork of Owl Creek. The total land involved in this area is 8,890 acres. Of this total, 7,100 acres are federal minerals. The significant resource values within the area include watershed, steep slopes, visual resources, elk winter range, and cultural values.

Resource inventories of the area are lacking. The inventories should be completed by December 1, 1978. They will help determine if the area should continue in the no-leasing category. Information contained in this analysis and the resource inventories will be used to make a final decision on this no-leasing area.

Operations

Once a federal lessee or designated operator indicates that he wishes to explore on or develop a lease, he must meet several requirements. They include the following.

Preliminary Environmental Review A preliminary environmental review is required of all drilling proposals prior to entry on the ground to stake the location, access roads and other surface-use areas. The operator must furnish a map and explain the anticipated activity and surface disturbance to the district engineer, USGS, as well as the district manager, BLM. This permits the district manager to identify any potential conflicts with other resource values. If conflicts are noted, a joint conference or field inspection is held involving USGS, BLM, and the operator.

Application for Permit to Drill Prior to drilling on a federal lease or even road construction, the operator must submit an Application for Permit to Drill (APD). The APD includes a surface-use and operations plan. Where

private surface is involved, it should include a copy of the written agreement between the lessee or operator and the surface owner. A letter from the lessee or operator setting forth rehabilitation requirements agreed to with the surface owner is acceptable.

The APD provides operations and geologic information required by the USGS. The surface use and operations plan must permit assessment of the environmental effects expected from the proposed project.

USGS sends this information to the BLM district manager, who reviews the plan and recommends surface-protection stipulations for the approved permit. The BLM must decide at this time if it desires to obtain the well as a water well if oil or gas is not encountered in usable quantities.

Approval of Operations Before repairing, deepening, or conditioning an existing well, a detailed written work plan must be submitted to USGS.

In existing fields, operators are also required to submit for USGS approval plans for new construction, reconstruction, or alteration of existing facilities, when additional surface disturbance will result.

Abandonment Well abandonment requires prior approval by the USGS and the BLM, which may require additional surface rehabilitation. These requirements are normally part of the approved abandonment plan. Abandonment will not be approved until surface rehabilitation work required by the drilling permit or abandonment notice is complete and required vegetation is established to the satisfaction of the BLM district manager.

Water Well Conversion If the BLM has decided to acquire the well as a water well, it must assume responsibility at the time of abandonment. The operator will plug the well at the bottom of the desired fresh-water zone and leave casing in place. The operator then will begin surface cleanup as required. The BLM must reimburse the operator for casing and labor to complete the well.

Other Requirements The Environmental Protection Agency (EPA) has issued regulations affecting all oil and gas lessees and operators (Title 40 CFR, Part 112). These regulations require owners or operators to prepare Spill Prevention Control and Countermeasure Plans (SPCC Plan). EPA does not make special inspections to see that operators have SPCC Plans. They can call for one from an operator if they desire, however, and if an operator does not provide one he is subject to a fine. After a hazardous material spill, EPA usually calls for the operator's SPCC Plan.

Oil and gas operators must meet several requirements of the Department of Transportation and the Interstate Commerce Commission.

State Agencies Oil and gas operators are required to receive permission to drill from the Wyoming Oil and Gas Conservation Commission, prior to operations. No surface development plan is required by the state.

If a well is a dry hole, operators are required to follow state procedures for plugging.

If a well is productive, the state requires notice and a monthly report. A completion or recompletion report is also required. The Oil and Gas Commission is interested only in production and conservation of the oil and gas. Surface protection requirements are a matter between the surface owner and the operator. The State Commissioner of Public Lands issues state leases and he also holds operators' bonds. He releases such bonds whenever the surface owner or lessee is satisfied. Monetary settlement is acceptable to the state in lieu of rehabilitation.

The Oil and Gas Commission has final authority on any well location variances. They also must approve unit agreements. They control water and gas injection systems and underground gas-storage projects. The USGS works with them on this, but the state has final authority.

Oil and gas operators are regulated by the State Department of Environmental Quality (DEQ). DEQ issues burning permits, if needed, and production-water discharge permits.

Local Actions County governments are not involved with oil and gas operators except as concerns roads. BLM is not familiar with any local agreements in the Grass Creek area.

The petroleum industry is very active in Wyoming. The Petroleum Association of Wyoming, headquartered in Casper, is the state chapter of the Rocky Mountain Oil and Gas Association (RMOGA), headquartered in Denver. The major producers belong to this association.

USGS, BLM, and RMOGA are jointly working on guidelines for surface protection and operational requirements. This type of cooperation should help solve surface protection and compliance problems.

Exploratory Drilling

Drilling does not begin until a lease has been acquired by the operator. In cases where preliminary investigations are favorable and warrant further exploration, exploratory drilling may be justified. More precise data on the geologic structure is obtained by stratigraphic tests using shallow drill holes. Suspected oil and gas deposits may be confirmed by wildcat drilling of deep holes.

Stratigraphic Tests "Strat" tests involve drilling small, shallow holes to supplement seismic data. By taking samples as drilling proceeds, the exact nature of near-surface structural features can be determined. Generally, stratigraphic test holes are drilled 100 to 500 feet deep in order to locate geologic indicator formations.

The drilling is accomplished either by rotary (boring) drills or percussion (hammering) drills. As chips of rock are cut away at the bottom of the hole, they are brought to the surface by a high-pressure air flow or a flow of drilling mud. These chips are collected, bagged, and identified as to the depth at which they originated. They are then studied by a geologist to determine composition, age, and possible formation. The geologist looks for a geologic marker zone or formation to correlate this geologic and geophysical data to actual subsurface structure. When this is accomplished, a subsurface geologic map can be prepared.

Truck mounted drilling equipment for strat tests is fairly mobile; therefore, roads and trails to test sites are temporary and involve minimal construction. The drill sites are about 30 x 30 feet and are often placed in the center of a new or existing trail to avoid clearing a pad. One to three days are required to drill the stratigraphic hole, depending on depth and hardness of the bedrock. In areas of shallow, high pressure, water bearing zones, casing may be required to keep water out of the hole.

Wildcat Wells Wildcat wells are deeper tests, require larger drilling rigs with support facilities, and may disturb a larger surface area than stratigraphic tests. Required facilities include roads, drill pads, mud pits, and — in some cases — camps and airports. Nationally, approximately 1 out of every 16 wildcat wells produces significant amounts of oil or gas. However, only 1 out of every 140 wildcat wells produces enough to be financially successful. The well site is normally selected on the basis of prior airborne and surface investigation, geological and geophysical surveys, stratigraphic tests, and data from producing and abandoned wells in the area.

Upon decision to drill the wildcat well, a heavy-duty road is built to move the drilling rig and other equipment to the location. The shortest route feasible is used to reduce the haul and costs. Roads may cross small streams with or without the use of culverts and are not designed for permanent use.

The well site — usually about two acres — is cleared of all vegetation and graded nearly flat. The drill pad and roads may be gravelled. The drilling rig, mud pumps, mudpit, generators, pipe rack, and tool house are built on the drill pad. Other facilities such as storage tanks for water and fuel are located nearby.

From 50,000 to 100,000 gallons of water a day are required for mixing drilling mud, cleaning equipment, cooling engines, and other uses. A surface pipeline may be laid to a stream or a water well, or water may be trucked to the site.

The rigs are very large and must be moved in pieces, generally on large trucks.

Drilling is started by "spudding in" the well, that is, starting the hole. Oftentimes, a short piece — 10 to 20 feet — of conductor pipe is forced into the ground. The initial drilling proceeds rapidly and generally the string of surface casing is set before harder, deeper formations are encountered. The surface casing is a long length of steel pipe which is cemented into the well to protect against water or rock getting into the hole. It is smaller in diameter than the conductor pipe but large enough to allow subsequent lengths of casing to be set as the well is deepened. Also, blowout preventers are necessary in case a zone containing high-pressure gas, water or oil is drilled into. Without blowout protection, the contents of this zone could blow all the drilling mud out of the well and come gushing out.

As drilling progresses, samples of drill cuttings are cleaned, dried, sacked, and labeled. A geologist examines them to determine composition, porosity, and oil or gas staining. When the drill cuttings give a good indication of oil or gas, the geologist may decide to conduct further tests. Testing may be by drill stem test with special equipment, or coring may be used to recover rock samples. Mud logging is often used to detect hydrocarbon shows and potential high pressure zones.

During or at the completion of drilling, the well is logged. Logging involves the measuring of physical characteristics of the rock formations and associated fluids, with instruments lowered to the bottom of the well. As the equipment is raised to the surface, the instruments record various data from each formation passed. After study of the well logs and drill stem test data, the geologist decides whether the well has encountered sufficient quantities of oil or gas in a pay zone to warrant completion of the well.

Completion requires installation of steel casing between the surface casing and the pay zone. The casing is selectively cemented, to provide stability and to protect specific zones, and then perforated adjacent to the suspected producing formation. If the formation does indeed produce oil or gas, the property is developed. If the formation does not produce, the well may either be extended to a greater depth or abandoned.

Only three wildcat wells were drilled in the Grass Creek area during 1975. All other drilling was in known fields. No statigraphic test holes were drilled in 1975.

Development

If the well yields oil or gas in commercial quantities, development begins. If formation pressure is sufficient to raise oil to the surface, the well is completed as a flowing well. Several acid or fracture treatments may be tried before a well is determined to be non-flowing.

If the well is completed as a free flowing well, the well head is simply closed off using a device known as a "Christmas tree" which consists of various valves and pressure regulators which are used to control oil or gas flow to facilities used in the production phase. If the well is a gas discovery, the operator is allowed to flare gas for a short period of time to determine capacity before shutting the well in.

Quite often, however, the producing zone will not have enough pressure to force the oil to the surface. In this situation, the oil must be pumped to the surface using "artificial lift" methods. When pump installation is complete, the well normally is tested for a period of days or months to determine whether the producing zone is adequate to support additional wells. More detailed seismic work may locate the petroleum reservoir more precisely. Diagonal seismic lines tying previous lines to the discovery well may be required. The discovery well may also be studied to correct previous seismic work and provide more accurate subsurface data.

A well spacing pattern must be established before development drilling begins. Information considered in establishment of a spacing pattern includes data from the discovery well on: porosity, permeability, pressure, composition, and depth of formations in the reservoir; well production rates and type (predominantly oil or gas); and the economic effect of the proposed spacing on recovery.

Most spacing for production from federal leases is a minimum of 40 acres per well. When larger spacing units are established, they are usually in multiples of 40 acres.

Most gas well spacing for production from federal leases uses units of 160, 320, or 640 acres per well.

Spacing for both oil and gas wells is based on the production formation. If a field is producing from more than one formation, the surface location of the wells may be much closer than 1 per 40 acres.

The Wyoming Oil and Gas Conservation Commission and the U.S. Geological Survey control spacing for oil and gas wells in the state. All wells must be in the center of a 40-acre legal subdivision with a tolerance of 200 feet in any direction. Spacing to most efficiently produce a formation is dependent on such factors as reservoir characteristics and drive mechanism. If a producer can show that different spacing is needed for maximum recovery, the state and federal agencies make exceptions to the rules. Many oil and gas fields in the state are producing on spacings other than 40 or 640 acres.

Once well spacing has been approved, the operator plans development of the lease. The procedures for drilling development wells are about the same as those for wildcat wells, except that there is usually less subsurface sampling, testing, and evaluation. Surface uses for development drilling may include access roads, well sites, flowlines, storage tank batteries, facilities to separate oil, gas and water, and injection wells for salt water disposal. Access roads usually are better planned and constructed than for wildcat wells.

When an oil field is developed on the current minimum spacing pattern of 40 acres per well, the wells are 1,320 feet apart in both north-south and east-west directions. If a section (a square mile) is developed with 16 wells, at least four miles of access roads are built. Although the size of most fields ranges from less than 1,000 acres to several thousand, a few major fields cover several townships. If a major field is discovered and developed on a 40-acre well spacing pattern, a township may have 576 wells and over 200 miles of road.

Surface uses in a gas field will be significantly less than in an oil field, because gas wells are usually drilled on 160-acre or larger spacing. A 160-acre pattern requires only four wells per section, and only two miles of access roads.

Surface use in an oil and gas field also may be affected by unitization of the leaseholds. In many areas containing federal lands, an exploratory unit is formed before a wildcat is drilled. The boundary of the unit is based on geologic data. The developers "unitize" the field by entering into an agreement to develop and operate it as a unit, without regard to separate ownerships. Costs and benefits are allocated according to agreed terms.

Unitization reduces the surface-use requirements because all wells are operated as though on a single lease. Duplication of field processing facilities is minimized, because development and operations are planned and conducted by a single unit operator. Unitization may also involve wider spacing than otherwise, resulting in fewer wells.

The rate at which development wells are drilled depends on such factors as whether the field is on a lease basis or unitized, the probability of profitable production, the availability of drilling equipment, protective drilling requirements, and the degree to which limits of the field are known.

The most important factor in further development may be the quantity of production. If the discovery well has a large capacity and substantial reserves are indicated, development drilling usually proceeds at a fairly rapid pace. If there is some question as to whether reserves are sufficient to warrant additional wells, development drilling may occur at a much slower pace. An evaluation period to observe production performance may follow between the drilling of successive wells.

Development on an individual lease basis may proceed more rapidly than under unitization, since each lessee must drill his own well to obtain production from the field. On a unitized basis, however, all owners within the participating area share in a well's production regardless of whose lease the well is on.

Drilling in an undeveloped part of a lease, to prevent drainage of petroleum to an offset well on an adjoining lease, is frequently required in fields of intermingled federal and privately-owned land. The terms of federal leases require such drilling if the offset well is on non-federal lands, or on federal lands leased at a lower royalty rate.

Many fields go through several development phases. A field may be considered fully developed and produce for several years, and then a well may be drilled to a deeper pay zone. Discovery of a new pay zone in an existing field is a "pool" discovery, as distinguished from a new field discovery. A pool discovery may lead to the drilling of additional wells — often from the same drilling pad as were existing wells — with the bore holes separated only by feet or inches. Existing wells may also be drilled deeper.

Production

Production in an oil field begins soon after the discovery well is completed and often concurrently with development operations. Temporary facilities may be used at first, but as development proceeds and reservoir limits are learned, permanent facilities are installed. The extent of such facilities is dictated by the number of producing wells, expected production, volume of gas and water produced with the oil, the number of leases, and whether the field is to be developed on a unitized basis.

Production in a gas field does not begin until the pipeline to a market has been constructed. Sales pipelines are not justified until sufficient gas reserves are proved by drilling operations. Gas wells are often shut-in after completion, for periods ranging from months to years, until pipeline connections are available.

Much of the gas in the Big Horn Basin contains hydrogen sulfide (H_2S). Hydrogen sulfide is a highly toxic and flamable gas. In general, most gas produced from formations below the Frontier contains hydrogen sulfide in varying amounts. Presence of hydrogen sulfide in a formation can cause problems while drilling, as well as during production. High carbon steel, used for drilling and casing deep holes due to its high strength, will shatter like glass when exposed to high concentrations of hydrogen sulfide. Natural gas containing significant amounts of hydrogen sulfide is known as "sour gas." The hydrogen sulfide must be removed before the gas enters a commercial pipeline.

If sour gas is produced in quantities insufficient to justify this removal, it must be flared. Sour gas is flared at Worland, Wagon Hound, Gebo, Golden Eagle, Grass Creek, and Walker Dome fields. Even in oil wells producing from formations containing hydrogen sulfide, a constant hazard to personnel exists from hydrogen sulfide dissolved in the produced oil. Hydrogen sulfide smells like "rotten eggs" in low concentration, but prolonged exposure tends to dull the sense of smell. Hydrogen sulfide is heavier than air and will concentrate in low-lying areas and depressions. It forms an explosive mixture with air in concentrations over four percent by volume.

A gas sweetening plant was operated in the Worland field in the past. Such plants produce elemental sulfur from hydrogen sulfide in the natural gas. At present, no such plants are operating in the Grass Creek area. All sour gas is either flared or piped elsewhere for sweetening. Sweet gas from Grass Creek and Little Grass Creek fields, as well as from Golden Eagle, is piped to Thermopolis for use there. Gas from the Worland field enters the Montana-Dakota Utilities interstate line, and gas from Little Buffalo Basin is piped to Oregon Basin and sold to Colorado Interstate Gas Company. Minor gas production from other fields is flared or used locally.

Well Facilities Wells in Wyoming require an artificial lift to bring the oil to the surface. Pumping and a technique known as "gas lift" are the two artificial lifts used. Naturally flowing wells and wells with gas lift facilities use a minimum of equipment at the surface and produce little or no sound. All pump systems require more surface equipment and make more noise than flowing wells and gas lift facilities.

Surface pumps are usually powered either by electric motors or internal combustion engines. Operators prefer electric motors because they make less noise, require less maintenance, involve less fire hazard, are more dependable, and can be more easily automated than internal combustion engines. However, internal combustion engines must be used in many oil fields where electric power is not available. If there is sufficient casinghead gas (the natural gas produced with the pumped oil), or another gas source is available, it may be used to fuel internal combustion engines. Butane and propane are also used as fuels. Single-cylinder engines operate at high noise levels, whereas multi-cylinder engines operate at lower noise levels.

Surface units used with sucker rod pumps are fitted with guard rails, belt drive shields, and fences for safety.

Most wells in the Grass Creek area have weak water pressure and require pumping. Both surface and subsurface pumps are used. The common horse-head pump is used extensively in the Grass Creek area. These pumps, as well as the accompanying tanks and other facilities, are usually painted and are visible for long distances.

Gas lift is used in some oil fields where low cost, high pressure natural gas is available, and where pressure in the petroleum reservoir is sufficient to force the petroleum part of the way up the well. The addition of gas lowers the specific gravity of the petroleum so that it flows to the surface. The system is quiet and uses little land. However, it will be used less in the future as supplies of high pressure natural gas decline.

Most gas wells produce by normal flow and do not require pumping. Surface use at a flowing well is usually limited to a 20-foot-by-20-foot fenced area containing a gas well "Christmas tree." If water enters a gas well and chokes off the gas flow, a pump may be installed to pump off the column of water. After the water is removed, the gas flows to the surface until water again chokes it off. Some gas wells may require almost continual water pumping.

Flowlines Crude oil is usually transferred from the wells to a central tank battery before it is transported from the lease.

Natural gas is often sold at the wellhead and transported directly off the lease. If processing is required to remove liquid hydrocarbons or water, however, the gas may be transferred to a central collection point prior to sale. On some leases, the production from several wells is piped to a satellite production station and then piped in a larger line to the storage batteries.

Oil and gas are transferred from the wells to central collection points in flowlines. There are about 100 miles of such crude oil lines in the Grass Creek area; the medium flowline size being four-inch steel pipe. Flowlines are buried, on the surface, or elevated.

Separating, Treating, and Storage Facilities If the oil produced contains gas and water, they are separated before the oil is stored in the tank battery. The treating facilities are usually located at a storage tank battery.

Low pressure petroleum that must be pumped from the well is treated in a single separation; high-pressure, flowing petroleum may require several stages of separation, with a pressure reduction accompanying each stage.

If enough casinghead gas is separated in the field to make it economical to process it for marketing, a plant may be built to remove gasoline, butane, and propane. Some of the remaining gas is used to fuel the plant. The remainder is sold. If the volume of casinghead gas produced in a field is insufficient to warrant treatment in a gasoline plant, it is usually used as fuel for pump engines in the field and as heating fuel for oil treaters. If the gas exceeds fuel requirements on the lease, it may be flared or vented to the atmosphere.

If water is produced with the petroleum, it is separated before the gas is removed. In primary operations, where natural pressures or gravity cause the petroleum in the reservoir to flow to the well bores, the degree of mixing usually is high enough to require chemical and heat treatment to separate the oil and water. Heat applied to the bottom of the treaters breaks the emulsion. The heat is supplemented in most cases by chemical emulsion breakers. In secondary production, where water injection or other methods are used to force additional petroleum to the well bore, the oil and water often are not highly emulsified. In this case, the oil and water may be separated by gravity in a tall settling tank.

After the oil and water are separated, the oil is piped to storage tanks. Storage tank batteries are usually located on or near the lease. They usually contain at least two tanks, so that at least one tank can be filling as the contents of the

other are measured, sold, and transported. The number and size of tanks vary with the rate of production on the lease, and the methods used to gauge the volume and sample the quality of the tank contents.

Disposal of Produced Water Although most produced waters are brackish to highly saline, some are fresh enough for beneficial use. These waters are discharged into drainages and, in most cases, eventually mix with natural surface waters. Some ranchers have filed claims on oil field water so they can use it for agricultural or livestock purposes. Wyoming law requires that discharge permits be obtained from the Department of Environmental Quality. The discharged water must meet certain water quality standards.

Because salt water seldom issues from heater-treaters completely free of oil, oil skimmer pits may be established between separating facilities and surface discharge.

When salt water is disposed of underground, it is usually introduced into a formation containing water of equal or poorer quality. It may be injected into the producing zone from which it came or into other producing zones. In some cases, this stimulates oil production. In other cases, it could reduce the field's productivity and may be prohibited by state regulation or mutual agreement of the operators.

In some fields, dry holes or depleted producing wells are used for salt water disposal; but, occasionally, new wells are drilled for disposal purposes. Cement is squeezed between the casing and sides of the well to prevent the salt water from migrating up or down from the injection zone into other formations.

Methods of Increasing Recovery Oil cannot be produced unless forces within the petroleum reservoir are great enough to drive the oil to the well bore. Primary production occurs when energy in the reservoir is sufficient to drive the oil to the well. When natural energy sources are inadequate, secondary production methods are used, involving gas or liquid injection.

Waterflooding is the method used in 97 percent of Wyoming's secondary recovery efforts. Water is injected into the reservoir to drive additional oil to the producing wells. On the average, a successful waterflood will double recovery.

The water supply is usually a brine obtained by drilling in the waterflood area. Fresh water is not desirable for waterflood purposes because it may form chemical bonds with clays in some reservoir rocks and reduce the permeability of the reservoir formation. When fresh water is used, the amount is not large (50-10,000 gallons a day), when compared to other uses of fresh water such as agricultural irrigation.

Grass Creek, Hamilton Dome, Little Buffalo Basin, and Prospect Creek fields in the study area are injecting water for secondary recovery purposes. Most water injected is produced by other wells in the fields. Little Buffalo Basin is the only field using gas injection for secondary recovery.

Abandonment

Dry wildcat and development wells are normally plugged before the drilling rig is removed.

Well plugging requirements vary with the rock formations, subsurface water, and the well. Generally, however, the hole is filled with heavy drilling mud to the bottom of the cemented casing. A cement plug is installed at the bottom of the casing, the casing is filled with heavy mud, and a cement cap is installed on top. In uncultivated areas, a pipe is required as a monument, giving location and name of well unless the requirement is waived by USGS. In agricultural areas, the casing may be cut off and capped below plow depth, and no monument is installed. Protection of aquifers and known oil and gas producing formations may require placement of additional cement plugs.

After plugging, the drilling rig is removed and the surface, including the reserve mudpit, is restored to its original condition as far as possible, according to requirements of the surface management agency.

In some cases, wells are plugged as soon as they are depleted. In others, depleted wells are not plugged immediately but are allowed to stand idle for possible later use in a secondary recovery program.

Truck-mounted equipment is used to plug former producing wells. In addition to the measures required for a dry hole, plugging of a depleted producing well requires a cement plug in the perforated section in the producing zone. If casing is salvaged, a cement plug is put across the casing stub. The cement pumpjack foundations are removed or buried below plow depth.

When an entire lease is abandoned, the separators, treaters, and other processing and handling equipment are removed and the surface restored. Surface flow and injection lines are removed but buried lines are usually left in place.

Upon abandonment, a well useful as a water producer may be acquired by the surface owner from the oil and gas operator. In this case, the well is cemented below the water-bearing formation and then completed as a water well.

Alternatives

The National Environmental Policy Act (NEPA) of 1969 does not require analysis of such actions as posting tracts for lease or approving lease applications. However, Section 102(2)(D) of the Act requires the responsible agency to "study, develop and describe appropriate alternatives to the recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources."

The alternative to the leasing program described in the "Proposed Action" is "no leasing." The no-leasing alternative means that no new oil and gas leases would be issued by the BLM. Current leases would not be renewed as they expire. Leases under production would not be renewed when production ceases.

III. DESCRIPTION OF THE EXISTING ENVIRONMENT

Air

Movement Patterns

Prevailing winds in the study area are from the southwest, having an average velocity of around five miles per hour. However, storm fronts and accompanying high winds usually come from the northwest. Such storms are most frequent during late spring and early summer but do occur from time to time year around. Rain or snow sometimes accompanies the storms.

Temperature

Within the Big Horn Basin, the mean temperature curve reaches a maximum between 30 and 40 days after June 21, the time of maximum solar radiation. The mean temperature curve reaches a minimum between 30 and 40 days after December 21, the time of minimum solar radiation. Thus, July is the warmest month and January the coldest. (See Figures 2-5.)

Because of Wyoming's elevation above sea level, the state has a relatively cool climate. Above 6,000 feet, temperature seldom exceeds 100°F. The warmest parts of the state are at the lower elevations in the Big Horn Basin and along the east-central and north-central borders of Wyoming. The highest recorded temperature was 114°F at Basin in the Big Horn Basin, July 12, 1900. The average maximum temperature during the 30-year period for Basin during July is 92°F.

For most of the non-mountain stations in the state, however, July mean maximum temperatures range between 85° and 90°F. Summer nights are almost always cool through the state since outgoing radiation loss from the surface is rapid because of the thin, dry air. Daily ranges of 35° to 45°F between the maximum and minimum temperatures are common.

In winter, rapid and frequent temperature changes are the pattern. Usually there are fewer than ten cold waves in Wyoming during the winter, most of the state recording fewer than half that number. Most of the cold air masses moving from Canada tend to move southeasterly and later easterly in these latitudes. Consequently, those areas of Wyoming east of the Big Horn Mountains and east of the Laramie range are just on the western edge of the Canadian air mass for just a few days. Meteorological phenomena causing this are the prevailing westerly winds and the fact that the heavy cold air is sliding downhill eastward across the plains. Occasionally, the general atmospheric circulation is such that a cold air mass can move southward and cover the entire state, giving Wyoming its coldest weather.

Many air masses are too shallow, 3000 to 4000 feet or less, to move across the mountain range such as the Big Horns. But when they do, the cold air may be trapped in areas like the Big Horn Basin, causing cold temperatures to persist for longer periods of time there than east of the Big Horns.

The climate of the study area is characterized by hot, dry summers and cold, dry winters. Temperature extremes range from well over 100°F in summer to -50°F in winter. Climatological records are available for the following locations within or on the fringes of the study area — Basin (elev. 3,837 feet), Sunshine No. 3 SW near Meeteetse (elev. 6,835 feet), Thermopolis (elev. 4,313 feet), Worland (elev. 4,061 feet). Annual temperature data for the above locations are shown on the following Figures 2-5.

Precipitation varies widely in the study area. Annual precipitation varies from 6.18 inches at Basin to over 30 inches in the southwest corner of the unit on Upper Owl Creek. The general trend is for precipitation to be lowest in the northeast corner of the planning unit and to increase to the highest levels in the southwest corner.

Most stations show a typical pattern of precipitation. In the average year, December, January, and February are the driest months. April, May, and June are generally the wettest months. Precipitation decreases in July and August but often has a secondary peak in September before dropping to the winter minimum.

During the winter period, the prevailing westerly winds are the strongest. Moisture from the west coast generally doesn't reach the Big Horn Basin because of the numerous mountain ranges between the Basin and the coast. This accounts for the low precipitation during the winter months. Precipitation during the months from October to March usually falls as snow. This period accounts for approximately 40 to 45 percent of the annual precipitation.

The prevailing westerlies decrease during the spring and summer months, allowing new circulation patterns to occur. During this period moist air can move from the Gulf of Mexico into Wyoming. Air movement from the Gulf is upslope and the cooling causes moisture to fall. Much of this precipitation comes as showers rather than general rains. The clouds from which shower activity occurs are frequently so high that much of the precipitation evaporates before hitting the ground. Thunderstorm activity peaks during the summer months, particularly along the southwest border of the study area.

Suspended Particulates

Suspended particulate sampling is conducted by the Wyoming Department of Environmental Quality (DEQ) in the Big Horn Basin at Cody, Lovell, Meadowlark Lake,

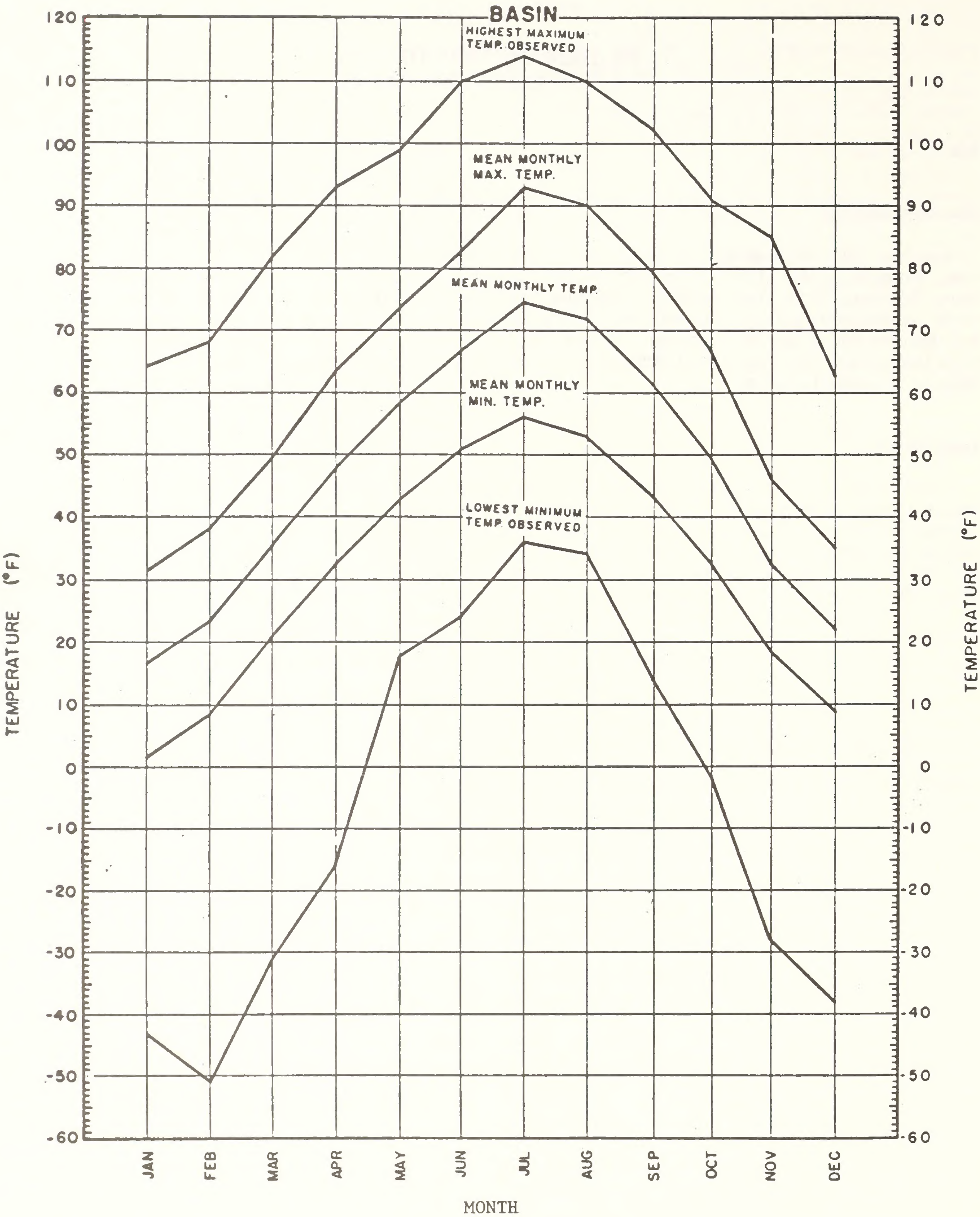


FIGURE 2—Annual Temperature Data for Basin, Wyoming

The following temperature graphs from Bulletin 415, University of Wyoming, Agricultural Station, June, 1964, based on records from 1931-1960.

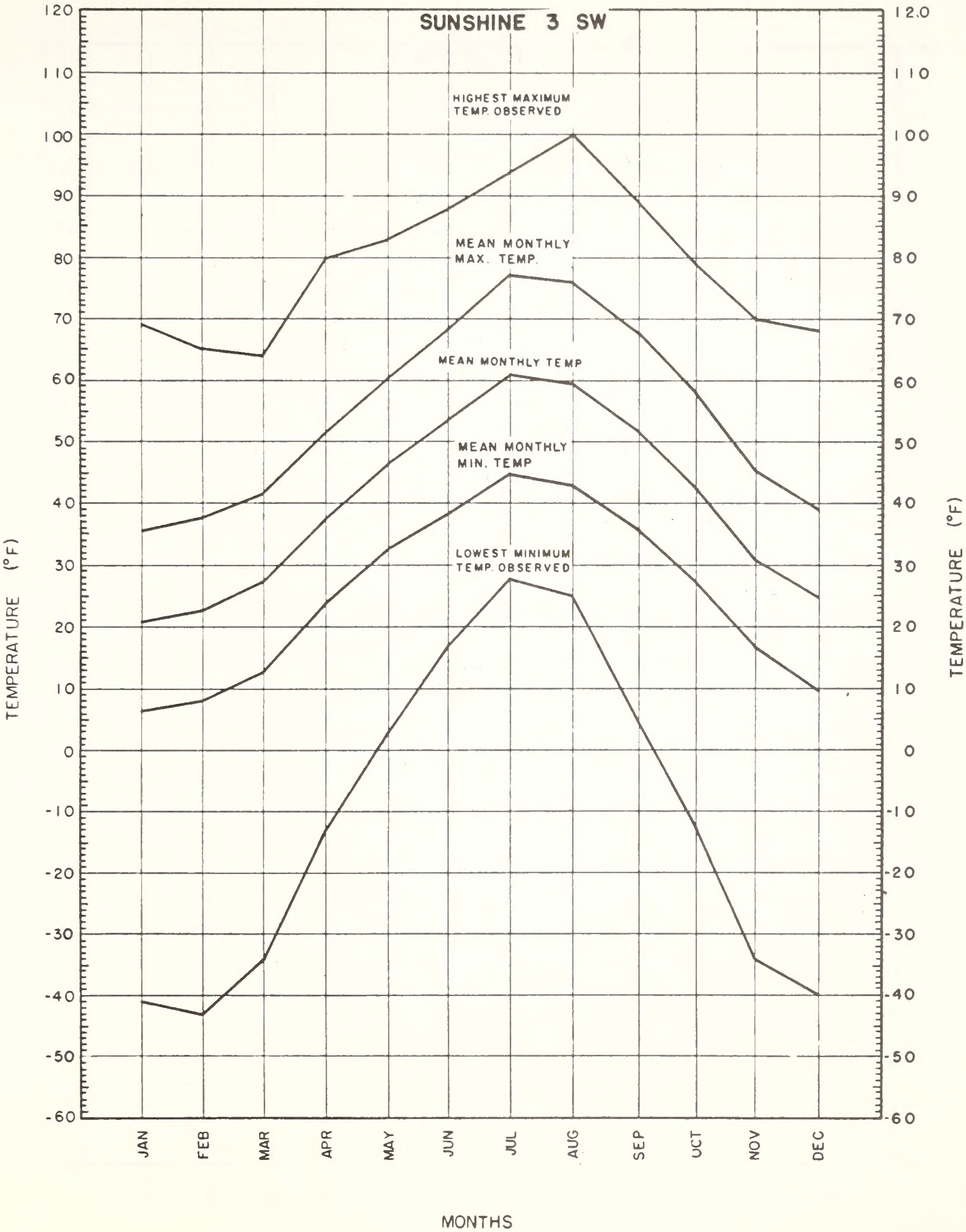


FIGURE 3—Annual Temperature Data for Sunshine 3SW
(near Meeteetse, Wyoming)

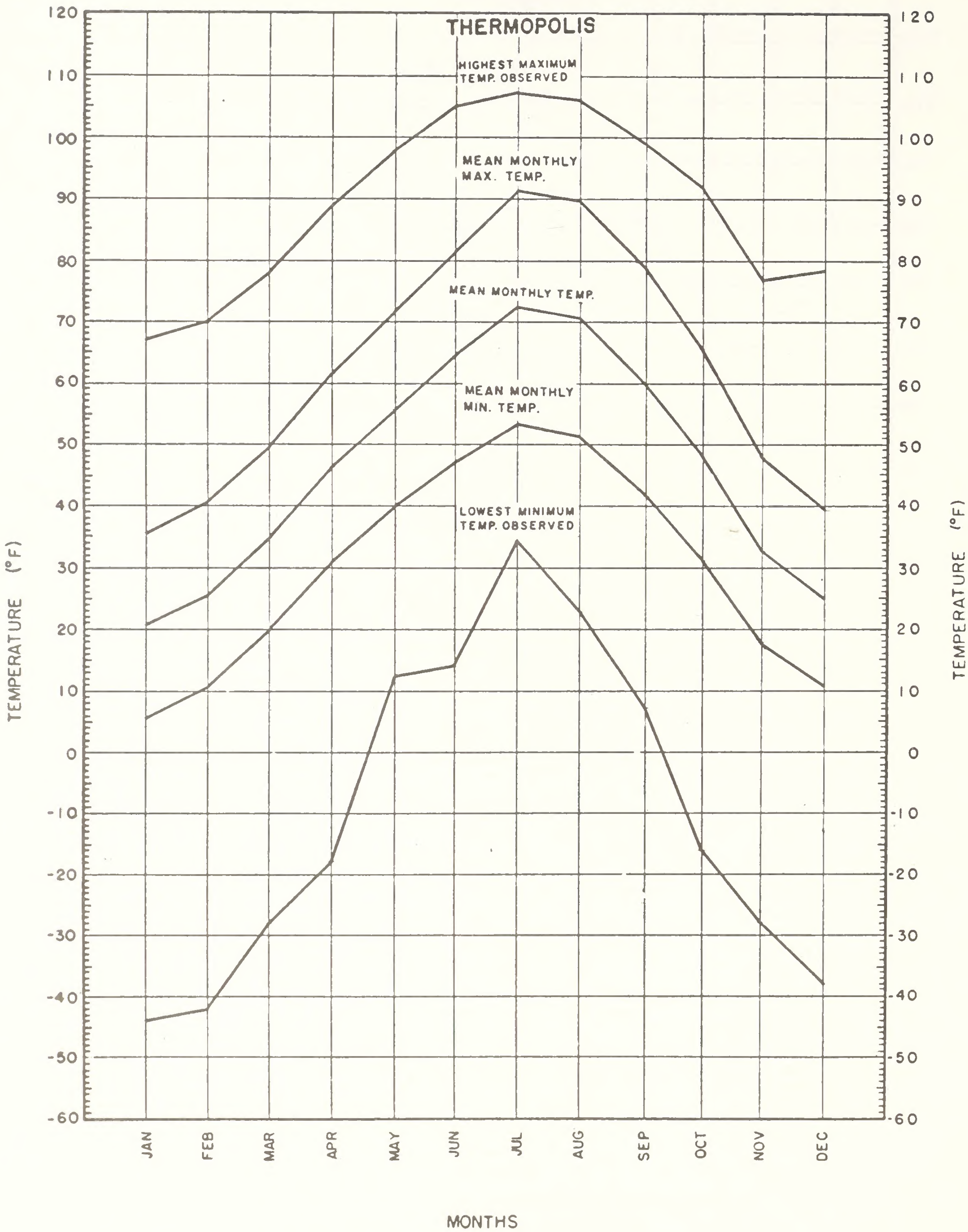


FIGURE 4—Annual Temperature Data for Thermopolis, Wyoming

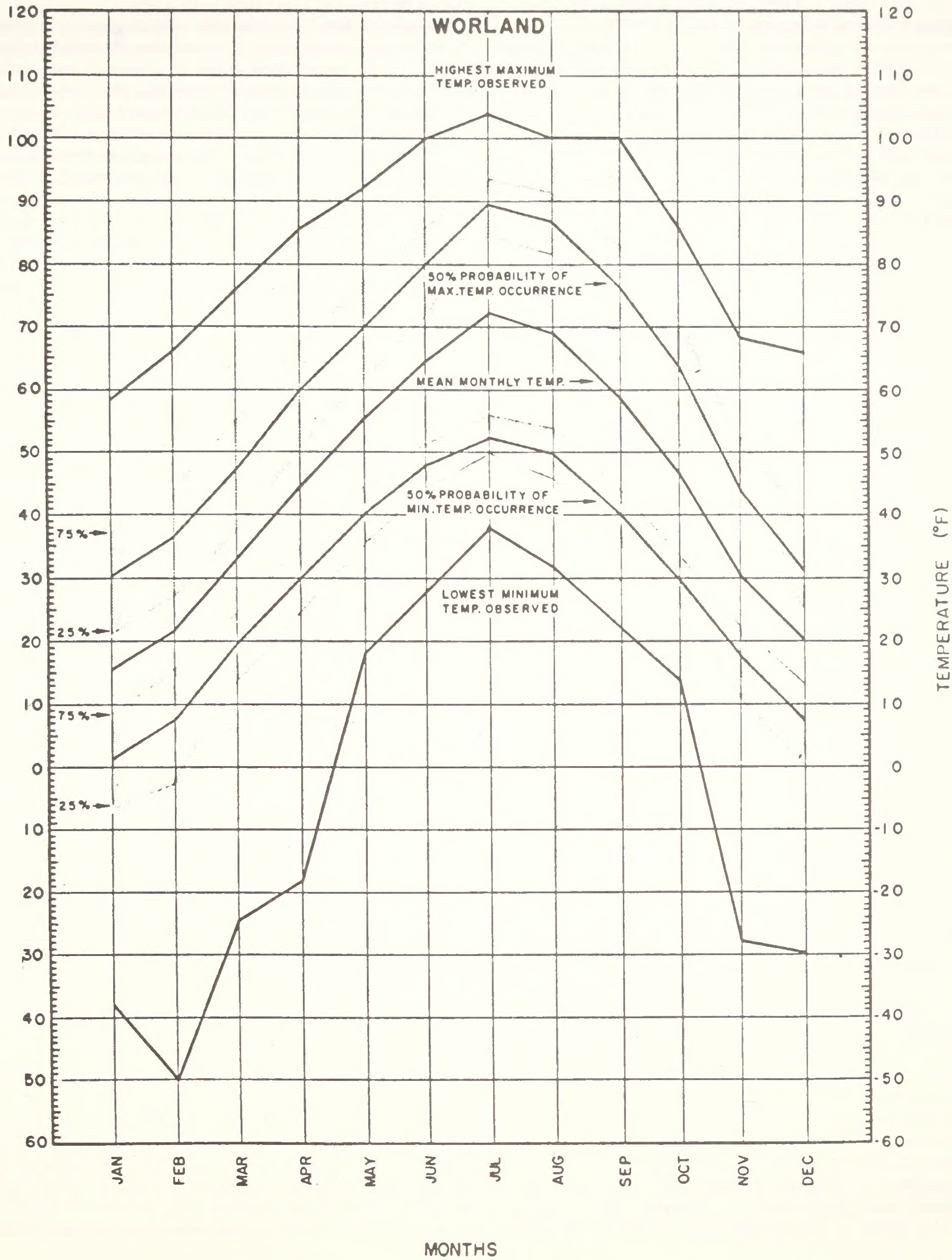


FIGURE 5—Annual Temperature Data for Worland, Wyoming

Thermopolis, and Worland. Those particulate sampling data are on Table 3. DEQ installed a particulate matter sampling station at Meeteetse in January 1977.

Air quality sampling was done on the average of about every six days at each location. As indicated, no sampling was done during some months. (The Worland and Thermopolis stations were established in 1976.) Since the sampling data are for one year only or less and sampling was irregular and infrequent, the reliability of the data is uncertain. Variables such as sampling technique and place of collection could exist. Regardless, this data is all that is known to be available.

TABLE 3
Particulate Matter — mg/m^3
Monthly Averages (1975)[1]

	Cody	Lovell	Meadowlark
Jan	—	17.30	5.80
Feb	—	—	3.75
Mar	21.50	24.75	4.40
Apr	38.60	30.00	12.00[2]
May	45.75	46.25	—
Jun	45.40	35.75	12.30
Jul	49.50	76.00[2]	—
Aug	34.80	68.80	(23.00)[2]
Sept	31.40	47.75	8.00
Oct	21.80	—	5.80
Nov	25.50	—	1.66
Dec	7.50	—	—

	Thermopolis (1976)	Worland (1976)
Jan	—	—
Feb	—	—
Mar	—	—
Apr	—	—
May	—	—
Jun	—	—
Jul	30.00[2]	103.00[2]
Aug	18.60	43.75
Sep	14.40	48.60
Oct	20.00	58.00
Nov	20.80	66.00
Dec	33.50	38.00

[1]Data provided by Department of Environmental Quality, Division of Air Quality, Cheyenne, Wyoming.
[2]Single measurement taken in these months.

The 1975 annual geometric means of suspended particulate matter for the above locations are:

Cody: 26 micrograms per cubic meter
Lovell: 36 micrograms per cubic meter
Meadowlark: 5 micrograms per cubic meter

The 1976 data are:

Thermopolis: 19 micrograms per cubic meter
Worland: 52 micrograms per cubic meter

According to DEQ, the ambient air standard for total suspended particulate matter for the state is 60 micrograms per cubic meter — annual geometric mean. A maximum 24-hour concentration of 150 micrograms per cubic meter cannot be exceeded more than once a year.

The above data indicates that annual geometric means of suspended particulate matter in the Meadowlark area are extremely low, which could be expected considering Meadowlark's location high in the Big Horn Mountains. Suspended particulate matter concentrations at Cody, Lovell, and Worland are considerably greater, which would also be expected due to low annual precipitation and agricultural lands surrounding those communities. Thermopolis' figure is significantly lower. Greater precipitation and less agricultural land in the area are possible causes. The annual geometric means of suspended particulate matter for all of the above locations are well below the state's ambient air standard of 60 micrograms per cubic meter.

General observations within the study area indicate that dust and smoke constitute the major portion of particulate matter in the air. Much of the area is arid, sparsely vegetated and highly susceptible to wind erosion. Consequently, strong winds that accompany storms within the Big Horn Basin sometimes turn into dust storms of varying intensity and duration. If accompanied by rainfall, the dust storms last only a short time.

Irrigated farmlands along the Big Horn and Greybull Rivers are a major source of dust when the lands are fallow or dry and barren just after planting in the spring. The intensity of the dust storms is directly proportional to the intensity of the winds.

Normal farming operations such as plowing, planting, discing, harrowing, and harvesting are all dust producing activities of varying intensity. Under normal weather conditions, the particulate matter added to the air by farming activities is confined to the farmlands and other lands in the immediate vicinity.

An extensive network of unsurfaced roads and trails covers most of the study area. Some of the roads have been improved and are maintained periodically. Many of these are used by persons engaged in oil and gas exploration and production activities, ranchers, farmers, recreationists, and others. Under normal, dry conditions within the area, vehicular use and other surface disturbance activities produce dust, increasing particulate matter concentrations in the air within small areas. Such activities probably have no measurable effect on particulate matter concentrations over the entire study area but do increase those concentrations over small areas.

Smoke is the other major particulate matter contributor. Primary source of the smoke is from the burning of crop residues and weeds and grasses along irrigation ditches on irrigated farmlands adjacent to the Greybull and Big Horn Rivers. Such burning occurs in early spring and late summer. Minor smoke producing activities in the area include burning of waste wood products at the sawmill in Grass Creek, flaring of sour gas from oil wells at the Golden Eagle oil field, occasional burning of sludge from oil tanks and oil from skimmer pits, and use of diesel engines and trucks in conjunction with oil and gas activities.

Gaseous Pollutants

Major activities within the study area include oil and gas exploration and production, farming, ranching, and recreation use including hunting, sightseeing, and off-road vehicle use. All of these uses in some way include operation of vehicles with internal combustion engines. Combustion products from motorized vehicle operation include carbon monoxide, hydrocarbons, nitrogen oxides, and sulphur oxides. Minor amounts of these pollutants are also produced from the combustion of heating oils and natural gas within the more densely populated areas along the Big Horn and Greybull Rivers.

There are 21 producing oil and/or gas fields within the study area. Operation of production facilities — wells, pipelines, storage tanks, separators, and treaters, etc. — and transportation facilities — pipelines, pumping stations, tank trucks, etc. — all contribute polluting emissions into the atmosphere to some degree. In many fields, gas produced along with oil is vented to the atmosphere from treaters, separators, and tank batteries. Sour gas — gas containing hydrogen sulfide — is produced at the Golden Eagle and Little Buffalo Basin oil fields and is flared, resulting in hydrocarbons and sulphur oxide pollutants being produced.

Normal oil production oparations within the study area oil fields include separation of produced water and oil using treaters and skimmer pits. In many of the less efficient operations, such pits are merely burned to remove oil from the produced water. Sludges that accumulate on the bottoms of oil storage tanks are removed periodically and either burned or disposed of in landfills. Accidents such as fires, rupturing of pipelines, and leakage from tanks and other facilities sometimes occur. The resultant evaporation or combustion of crude oils and gases adds a variety of pollutants to the air.

There is no known air quality monitoring program within the study area to monitor carbon monoxide, hydrocarbons, nitrogen oxides, or sulphur oxides. However, within oil fields known to produce hydrogen sulfide, oil companies routinely monitor the air for presence of that gas and provide protective breathing equipment for personnel working around production facilities. Flaring of natural gas containing hydrogen sulfide is a normal method of neutralizing the toxic effects of that gas.

Total oil and gas production from existing fields in the study area is declining. Past exploration activities and production have been limited mainly to the surface structural features of the Big Horn Basin. Drilling has been at relatively shallow depths along the east, south, and west fringes of the Basin. The central part of the Basin is still virtually unexplored. The increased price paid for oil and gas now warrants expanding exploration and deeper drilling in the central part of the Basin. Such oil and gas activity, although relatively minor, is presently occurring in the central and eastern portion of the study area. It can be expected to increase and persist for some time into the future.

Soils

Summary

Map 3 is a general soil map done by the Soil Conservation Service for each county that makes up the total area. The soil survey intensity shows only the major bodies of soils found in a given location and it identifies only the broader soil differences within three climatic zones.

Soils in the study area are typically alkaline, high in sodium with some layers of gypsum salts. Soil depths vary greatly from no soil on rock outcrops to greater than 60 inches on alluvium (water transported sediments). Varying amounts of soluable salts reach levels in some soils that affect their management potentials (reduced infiltration of water, limitation of nutrient availability, and reduction of water amounts available to plants). The C and F soils are extremely susceptible to the effects of compaction, especially those found on steep slopes, shallow soils, and wet bottom soils.

The most limiting factor in soil development is the extreme aridity of the climate of the M soils area.

Following are the major soil associations in the study area, keyed to Map 3. More specific information about the soil grouping can be found in the glossary of soils terms.

"C" Soils

"C" cold soils of the mountains and mountain valleys are developing on various kinds of parent material at an elevation of 5,500 to 12,000 feet.

C1 soils are developing in gravelly, cobbly and stony alluvium on floodplains, stream terraces and fans, and consist of the following associations: typic cryaqualls, typic cryoborolls.

C2 soils are on rough, very steep, mountainous areas with 50 percent or more rock outcrop. Areas are either barren or covered with alpine vegetation and consist of the following soil associations: lithic cryoborolls, typic cryoborolls, and pachi cryoborolls.

C3 — There are two soils in this association — lithic cryoborolls and typic cryoborolls. They are red soils with moderately high base saturation. One soil has more than 35 percent gravel in the profile, while the other one has less than 3 percent gravel throughout.

C5 soils consist of the following soil association: argic cryoborolls, argic lithic cryoborolls, argic pachi cryoborolls, lithic cryoborolls, and lithic rundolls.

"M" Soils

"M" soils are warm soils of desertic basins. Elevation ranges from 4,000 to 5,700 feet. Mostly, these soils are calcareous to the surface and are on moderate to steep slopes.

They are in a semi-arid climate and there is little or no leaching of soluble salts; therefore, most of the soils are salty throughout. These soils receive little natural moisture and in most years are dry more than half of the growing season. Many have physical properties that keep them dry such as a crusty surface that virtually precludes infiltration of water or they are very shallow over bedrock or of a coarse texture with little total waterholding capacity.

M1 soils are at elevations from 4,000 to 5,700 feet. M1 soils develop in alluvial deposits on floodplains, stream terraces and fans, and consist of the following soils associations: typic torrifluvents, ustic torrifluvents, typic torriorthents, fluventic haplaquipts, and typic haplargid.

M2 soils develop in redbeds and some limestones and sandy shales on rolling to steep, strong dissected uplands with many rock outcrops and consist of the ustic torriorthent soil association.

M3 soils develop in alluvial deposits on nearly level to sloping high terraces and consist of the following associations: typic torriorthents, typic torrifluvents, typic calciorthids, and typic camborthids.

M4 soils developing in shale on nearly level to sloping uplands with some narrow valleys with steep side slopes consist of the following associations: typic torriorthents and typic torrifluvents.

M5 soils developing in shale on strongly dissected, rolling to steep uplands with many shale outcrops consist of the following soil associations: typic torriorthents and ustic torriorthents.

M6 soils develop in interbedded sandstone and shale on undulating to rolling uplands. These are typic torriorthents. See M3 soils.

M7 soils develop in interbedded sandstone and shale on strongly dissected, rolling to steep uplands with some rock outcrops. These are typic torriorthents; refer to writeup under M3; they are the same.

"F" Soils

These soils are cool soils on mountain foothills and desertic basins from 5,700 to 7,000 feet elevation. These soils make up a rather narrow band of land area that is a transition zone between the timber areas and the dry desert conditions. It consists of the following three major mapped areas.

F1 soils develop in alluvial deposits on floodplains, stream terraces and fans. They are cold and wet and have a water table in the profile. Slopes are from one to six percent.

F3 soils develop in redbeds with thin, interbedded sandstone and limestone on rolling to steep, dissected uplands. There are many rock outcrops. Slopes are 6 to 60 percent.

F4 soils develop in interbedded sandstone and shale on strongly dissected, rolling to steep uplands with some rock outcrops. Slopes are 3 to 30 percent.

Glossary of Soils Terms

Typic cryaqualls — Medium textured over sand; they are cold and wet and have a watertable in the profile.

Typic cryoborolls — Medium texture with one percent or more organic matter in the surface and/or separated one from another if they have more or less than 35 percent gravel in the subsoil.

Lithic cryoborolls — Medium textured soil with less than 20 inches to bedrock. The soil surface has more than one percent organic matter and some areas have gravel subsoils. They are typically found on south slopes.

Pachi cryoborolls — These are high in clays with depth of organic matter to 20 inches. They occur in areas that receive runoff from surrounding areas.

Argic cryoborolls — Soils in this subgroup have dark colored surfaces and do not have hard or soft rock within one meter of the surface.

Argic lithic cryoborolls — These have hard bedrock within 20 inches.

Argic pachi cryoborolls — This is free of rock within one meter of the surface and occurs in depressed areas or areas that receive excessive runoff.

Lithic rundolls — These are less than 20 inches deep over limestone, and have gravel in the profile and have 40 percent lime mixed with the gravel.

Typic torrifluvents — These occur at lower elevations in the desertic basin. They are more common on the floodplain, are stratified with different textures throughout, and are calcareous to the surface.

Ustic torrifluvents — These occur in a slightly higher rainfall area than the typic.

Typic torriorthents — These are like the typic torrifluvents. They are loamy, clayey, fine, and some are high in swelling-type clays. All are calcareous to the surface.

Fluventic haplaquipts — Soils in this subgroup are on the floodplain and have a seasonal water table within the subsoils. They are calcareous to the surface.

Typic haplargid — Soils in this subgroup are mapped according to depth to sand and gravel. One is less than 40 inches deep; the other soil is deeper than 40 inches.

Ustic torriorthents — Soils in this subgroup have light colored and medium textured surface and subsoils and are calcareous to the surface. They are mapped both as shallow and deep soils.

Typic calciorthids — Soils in this subgroup have more than 15 percent lime in the subsoil and more than 35 percent gravel in the subsoil. They are light colored and characteristic of low rainfall areas.

Typic camborthids — They occur in the same area as the calciorthids, but lack the high lime zone, are deeper and lack the gravel in the subsoil.

Geologic Structure

The Big Horn Basin is a major petroleum producing area within the Rocky Mountain area. In terms of present and potential mineral development, oil and gas — now and in the foreseeable future — far overshadows all other mineral commodities in terms of extent of development and economic value in this area.

The Big Horn Basin is one of several large intermontane basins in Montana and Wyoming which have broad central areas covered by rocks of tertiary age, while the older, underlying sedimentary rocks are exposed along the

margins adjacent to the bordering mountain uplifts. This basin is both a topographic and structural basin and is elliptical in outline. The structural basin was formed during the Laramide orogeny in late Cretaceous and early Tertiary time.

As a result, the younger, relatively undisturbed Tertiary rocks unconformably overlie and conceal the major structures developed in the older Paleozoic and Mesozoic rocks. Where these older rocks are exposed on the margins of the basin, there is a prominent series of folds. This exposed marginal belt of folds is the site of almost all of the known oil and gas fields discovered to date. Folds on the margin of the Basin commonly are elongate, asymmetrical anticlines and synclines. The folds are commonly prominent geologic features, easily detected, and as a result were the site of most early oil and gas tests on the basis of seeps or anticlinal structures.

The first discovery of petroleum in the Big Horn Basin is reported to have been in 1884 from an oil spring at Bonanza.

The bedrock in the study area is, for the most part, either exposed or covered by a very thin mantle of alluvium. The geologic age of rock formations exposed range from the Quaternary age deposits of alluvium to Mississippian age deposits of limestone. A general description of the stratigraphic column is as follows:

Quaternary:

Alluvium, terrace and pediment surface deposits of silt, sand, gravel, and cobble.

Tertiary:

Volcanic rock: Consisting of andesite and basalt; mostly early basic breccia and agglomerate.
Willwood Formation: Consisting of varicolored clay, sandstone and shale, lenticular beds of quartzite conglomerate. Forms badlands.
Fort Union Formation: Consisting of thin-bedded, light colored sandstone and conglomerate; drab to olive-brown shale with some red shale in upper part. Forms badlands.

Cretaceous:

Lance and Meeteetse Formations: Consisting of thick-bedded buff sandstone and drab and green shale of Lance Formation underlain by gray and white clayey sand and sandstone, brown shale and bentonitic clay of Meeteetse Formation. Locally upper part of Meeteetse contains thin coal beds.
Mesaverde Formation: Consists of interbedded sandstone and shale in upper part; lower part massive sandstone with coal beds.
Cody Shale Formation: Consists in upper part of buff sandy shale and thinly laminated buff sandstone; lower part dark gray thin-bedded shale.
Frontier, Mowry, and Thermopolis Shale Formations: Frontier consists of thick lenticular gray sandstone, gray, brown and carbonaceous shale and bentonite; Mowry consists of gray and brown shale in large part siliceous, with numerous bentonite beds; Thermopolis shale consists of soft black shale with numerous bentonite beds, Muddy sandstone member about 200 feet above base.

Cretaceous/Jurassic:

Cloverly and Morrison Formations: Consisting of thin-bedded sandstone and shale with thin ironstone beds called the "rusty beds" at top, underlain by variegated shale and clay, sandstone, and local conglomerate.

Jurassic/Triassic:

Sundance, Gypsum Springs, and Chugwater Formations: Consisting of sandstone, green shale, and thin limestone beds underlain by red shale and gypsum.

Permian/Pennsylvanian/Mississippian:

Embar, Tensleep, Sandstone, Amsden, and Madison Limestone Formations: Embar consists of a sequence of limestone, cherts, phosphate rocks, shales, and sandstone; Tensleep consists of massive yellow, buff or white crossbedded sandstones; Amsden consists of a sequence of shales, white limestones, and cherty and sandy limestone; Madison consists of limestone.

Therefore, the area is — in the most part — a province of sedimentary deposits ranging from deposits of unconsolidated alluvium, sand and gravel through soft clays, shales and siltstones to hard siliceous shales, sandstones, and limestones.

Primary Characteristics

The most numerous geologic structures encountered in the area are anticlinal. A total of 19 anticlines and 2 synclines in the area are prominent enough to have been named. Practically all of them are producers of oil and gas. The northeastern portion of the area is near the center of the Big Horn Basin where the attitude of the formations is generally flat or of low degree of dip. As one progresses to the south, southwest and west, one approaches the perimeter of the Big Horn Basin where most of the previously mentioned geologic structures occur. Also, the general dip of the beds becomes greater, especially at the geologic structures where dips of 40 to 50 degrees are not uncommon. In the Thermopolis anticline just northwest of Thermopolis, some of the beds are slightly overturned.

Other prominent structures are Tatman Mountain in the northern portion; Squaw Teats in the western portion; the Absaroka Mountain Range in the western perimeter; the Owl Creek Mountains in the southern perimeter; the

Gooseberry badlands in the central portion; other various scattered badlands and various rimrock features common throughout the area.

Depth to bedrock is generally zero to just a few feet except in stream valleys containing alluvium or terrace deposits. Depth to bedrock in these areas may be as much as 50 feet but is usually much less.

Although the anticlinal structures were formed by a great deal of deformation and folding, the area could not be considered highly faulted. While there are some faults present, there are no highly faulted zones and none of the faults are active.

Mineralization

Other than the oil and gas that is found in the area, there are ten other minerals present in sufficient quantity and quality to warrant discussion, although they may not be commercially exploitable at the present time. Following is a discussion of the occurrence of these ten minerals. (See Map 4.)

Gypsum Gypsum beds 30 to 40 feet thick occur in the Chugwater Formation that encircles most of the Owl Creek Mountains lying just to the south and west of Thermopolis. Also, the Dinwoody Formation, stratigraphically just below the Chugwater, is reported to be almost entirely gypsum in this area. The Dinwoody varies from 15 to 60 feet in thickness in the Big Horn Basin.

Coal There are four identified coal fields in the area: the Grass Creek, Gebo, Meeteetse, and Basin fields. All of the Grass Creek field is completely within the area, about five percent of the Gebo field is outside the area, and about 60 percent of the Meeteetse and Basin fields is outside the area. The Wyoming Geological Survey Bulletin No. 50, "Mineral Resource of Wyoming," indicates that the total reserves of these four fields contain about 374,000,000 tons of sub-bituminous coal. Correcting for the percentage that lies outside of the area of analysis, this would be reduced to about 297,000,000 tons. This estimate includes both strippable and underground reserves; the major portion by far is underground reserves.

Phosphate Deposits of low grade phosphate are in the southeast corner around Thermopolis and in the southwestern corner of the area.

Sulfur Around Thermopolis there are known sulfur deposits associated with the gypsum beds.

Bentonite A recent survey conducted by BLM indicates that a resource of about 71,000,000 tons exists in this area around Thermopolis.

Wyoming is the major producer of sodic bentonite in the United States, with the Big Horn Basin district ranking second only to the Black Hills district. Bentonite mining began in the Basin in the early 1950's. Since that time, production and demand have increased approximately on an annual basis. Currently, there are four bentonite processing plants in the Basin, none of which is in the subject area. Total capacity of these plants is about 900,000 tons a year. Total production in the Basin for 1975 was 769,000 tons, valued at $7.7 million.

Today, the three major uses of bentonite are: the pelletization of low-grade iron ore (taconite); binder in foundry sands; and for drilling mud. Although demand for bentonite in the taconite industry is projected to increase, this may not be reflected in tonnage figures because of technological advances which allow the use of less bentonite than before. Foreign demand for foundry bentonite is expected to increase by 40 percent in the next 20 years while domestic demand is expected to remain stable. Total domestic demand for bentonite drilling mud is projected to more than double over the next 25 years. Demand for miscellaneous uses, such as binder in animal feed and civil engineering applications, is also expected to double in the next 25 years.

In view of the above, it is obvious the bentonite industry is enjoying a stable growth rate and will probably do so in the future. Growth will probably occur in the Big Horn Basin and Montana. Evidence of this growth is apparent in the Thermopolis area. There is and has been no bentonite mining in the Grass Creek area. A recent inventory conducted by the BLM indicates about 71 million in-place tons of bentonite in the Thermopolis area, approximately half of which is in the Grass Creek area. It occurs in both the Frontier and Mowry Formations of Cretaceous age which outcrop along the flanks of the Thermopolis and Shellbourne anticlines. Measured reserve estimates are not available.

Wyo-Ben Products, Inc., has recently announced plans for a bulk bentonite processing plant in the Thermopolis area. If constructed, one can expect mining operations to begin on the deposits discussed above. These deposits will be extracted by strip mining, hauled to the mill by truck, and shipped by rail to market.

Titanium There are three deposits of titanium bearing sandstone in the area. Two of them are on the flanks of the Grass Creek anticline and the other is near Cottonwood Creek on the northeast flank of the Waugh anticline. The Grass Creek deposit is the largest of the high grade, heavy mineral black sandstone deposits known in Wyoming.

Sand and Gravel There are abundant deposits of sand and gravel along the principal drainages, both in the stream flood valleys and the remnants of the terraces above the flood valleys.

Stone The area contains huge volumes of various types of rock that have commercial appeal, varying from common riprap material to dimension stone and moss-covered rock. Just west of Thermopolis is a deposit of oolitic limestone that produces flagstone and facing stone.

Geothermal The area immediately around Thermopolis is considered a geothermal area. The town of Thermopolis has a hot spring that has been developed for many years.

Change Agents

Other than that involved in the oil and gas industry, there is no major construction except for intermittent road construction.

Other than that involved in the oil and gas industry, the mining activity is restricted to sand, gravel, and stone deposits through mineral material disposal contracts such as free use permits, mineral material sales, and community pits. Also, a little coal is being strip mined (about 5,000 tons per year) from Coal Draw in the Grass Creek field. However, Western Energy Company has reserves of up to 20,000,000 tons of strippable, recoverable coal in the Grass Creek field associated with the small stripping operation and they are actively pursuing the development of this reserve. An underground mine (Roncco) and a coal lease in the Gebo field are presently not operating.

The sulphur plant north of Worland has been shut down for several years because of a lack of sufficient volume of sour gas.

Land Use

The study area includes 1,496,445 acres; 979,614 acres (65%) public lands administered by the BLM; 411,205 acres (28%) privately owned; and 105,627 acres (7%) owned by the State of Wyoming.[1]

Ownership Patterns

The patterns of land ownership within the study area have evolved over the years. The federal government initially acquired the lands from France in 1803 as part of the Louisiana Purchase. With statehood in 1890, the federal government granted Wyoming sections 16 and 36 in every township for the support of public education. That grant created the most distinct and uniform land ownership pattern in the area. Other state lands were acquired mainly through indemnity selections and exchanges with the federal government.

Water, topography, and soil are major factors that influence the pattern of private land ownership in the area. Early explorers and settlers recognized the agricultural potential of river bottoms and adjacent terraces and benches along perennial streams and rivers such as the Big Horn, Greybull, and Wood Rivers, and Gooseberry, Grass, Cottonwood, and Owl Creeks. Thousands of acres adjacent to those rivers and creeks were transferred into private ownership and developed as irrigated farmlands under the Homestead Act, the Desert Land Act, and the Carey Act. The strip pattern of ownership parallel to water courses generally results from topographic limitations for conveyance of water to the lands using gravity canal systems and flood irrigation techniques.

The other major factor which influenced the development of the present private land ownership pattern was the value of lands for grazing. While lands along major perennial stream drainages were valuable for agriculture, lands in the western and southern portions of the area were especially valuable for grazing due to their higher elevations, higher rainfall, and resultant higher production of native forage for livestock. Lands were selected and entered primarily by rancher homesteaders to control stockwatering places, to control access to and use of federal lands, and/or to acquire the better grazing lands.

Uses

Ranching Most of the rangeland in the study area is used for grazing of domestic livestock. In addition, many of the agricultural lands are used for livestock pasture after crops have been harvested, generally from late fall to early spring.

Ranch headquarters are scattered throughout the area with most being located along perennial streams and rivers. (See Domestic Livestock section in this chapter.)

Farming Agricultural lands in the study area are strips of private and state lands generally located along perennial streams and rivers in the area. All of the farmlands are irrigated since precipitation throughout the area is insufficient for non-irrigated agriculture.

Primary irrigation systems consist of stream diversion structures, gravity fed canals and laterals, and ditches for flood irrigation. Some farmers use sprinkler irrigation systems and other pump water through pipelines, irrigating with gated pipe systems. Use of irrigation systems requiring pumping is generally confined to lands located above existing gravity canal systems.

The major crops produced in the area are sugar beets, malting barley, corn, alfalfa, and hay. Minor crops include beans, oats, wheat, and rye. Farmers along the Big Horn River and along the lower stretches of the Greybull River, Cottonwood Creek, and Gooseberry Creek generally grow sugar beets and barley as cash crops. Sugar beets are processed at the Holly Sugar plant in Worland and malting barley is delivered at harvest time to local brokers for temporary storage pending shipment to various brewers. Sugar beets and malting barley are produced under contract with quotas and acreage limitations for producers. Corn, oats, alfalfa, and other hay are grown on other farmlands. Those products are sold for winter livestock feed and for fattening livestock in feedlot operations. Some farmlands are leased by ranchers for pasturing their livestock on sugar beet tops and other crop residues over the winter.

Irrigated farmlands along the upper reaches of the Greybull River, Wood River, Cottonwood Creek, Gooseberry Creek, Grass Creek, and Owl Creek produce alfalfa and other hay for supplemental livestock feeding through the winter.

Oil and Gas There are 21 producing oil and gas fields in the study area. These fields are within 21 known geologic structures (KGS) having a total area of about 55,000 acres, or about 3.8 percent of the total land in the study area. (See Map 1 for KGS and oil field locations.)

The acreage of surface disturbance within the study area resulting from oil field activities has been estimated for this study. Bare ground due to oil field activity is estimated

[1]From BLM master title plats by Wyoming State Office.

at 1,200 acres. The bare ground consists of areas around well sites, tank batteries, storage pits, roads, and field camps. The bare ground is usually surfaced with gravel, crude oil, or asphalt. Disturbed ground is estimated at 1,431 acres. The disturbed areas are those next to well locations, storage pits, pipelines, roads, tank batteries, etc. The disturbance varies from heavy excavation to just stripping of vegetation. These areas have some type of vegetative cover. Quite often they are covered by undesirable species such as thistle, cockleburs, halogeton, and cheatgrass. Natural revegetation by native plants is occurring on some areas, but repeated surface disturbance from oil field activities impedes the revegetation.

The estimated 2,631 acres of bare or disturbed surface in the oil fields represents 0.18 percent of all the lands in the study area and 0.28 percent of all the public lands in the area.

Seismograph lines, roads, and trails are found throughout most of the study area. During earlier seismic exploration operations, it was a common practice to use bulldozers to blade seismic lines, clear vegetation, and smooth out the terrain for drill rigs and other equipment. Roads and trails were constructed as needed without any planning or regulation. Some roads and trails were unnecessarily constructed, many in improper locations on steep slopes and highly erosive soils. Vegetative cover was destroyed and often not rehabilitated. The total acreage of surface disturbance from past oil and gas exploration activities would be difficult to compute. Some areas have revegetated naturally and some have been revegetated by reseeding — normally with crested wheatgrass, a non-native species.

Past exploration activities and production have been limited mainly to the surface structural features of the Big Horn Basin. Drilling has been at relatively shallow depths along the east, south and west fringes of the Basin. The deeper structures of the central part of the Basin are still virtually unexplored. The increased price paid for oil and gas now warrants expanded exploration and deeper drilling in the central part of the Basin. Such oil and gas activity, although relatively minor, is presently occurring in the central and eastern portions of the study area. It will probably increase and persist for some time into the future.

Roads and Highways Major highways within the study area include U.S. Highways 16 and 20 and State Highway 120. U.S. Highway 20 enters the area from the south through the Wind River Canyon, passes through Thermopolis and parallels the Big Horn River to Worland where the highway crosses the river, leaving the study area and joining U.S. Highway 16. U.S. Highway 16-20 then parallels the east side of the Big Horn River north to Manderson where it again crosses the river into the study area and follows the river north through Basin and on to Greybull, leaving the study area. Another major travelled route through the study area is State Highway 120 which begins at Thermopolis and extends northwesterly through Meeteetse. Other primary state highways within the area include State Highway 433 from Worland to Manderson, paralleling the west side of the Big Horn River; State Highway 431 (locally known as the Gooseberry cutoff) from Neiber to a point on State Highway 120 between Thermopolis and Meeteetse; State Highway 36 from Basin to Otto; and State Highway 170 which serves the Owl Creek area and Hamilton Dome.

All of the above highways are two lane, paved with asphalt. U.S. Highways 16 and 20 and State Highway 120 are major routes for tourist traffic coming west to Yellowstone and Grand Teton National Parks.

Railroads The Burlington Northern Railroad is the only railroad serving the study area. The railroad's single track line enters the area from the south through the Wind River Canyon, crosses the Big Horn River twice, enters Thermopolis and extends north paralleling the Big Horn River almost to Worland. The railroad crosses the Big Horn River again, leaving the study area and parallels the river north to Manderson where it crosses back into the study area. From Manderson north, the railroad parallels the left bank of the Big Horn River through Basin, crosses the Greybull River and leaves the study area. The railroad right-of-way is almost entirely on private farmlands along the Big Horn River.

The railroad is an important transportation facility in the Big Horn Basin. Various products and commodities produced in the area and in the Big Horn Basin are transported to market elsewhere by the railroad. Barley, refined sugar, cattle, sheep, processed meats, bentonite, and oil are major products and commodities shipped.

Pipelines There are two major pipelines that affect the study area. One is a 12-inch crude oil pipeline owned by the Platte Pipeline Company. The pipeline originates in the Lovell area and runs southerly through the Oregon Basin oil field, enters the study area northeast of Meeteetse, and runs southeast to a storage tank facility in the Winchester-Chatham area. The pipeline leaves the area in the Kirby-Lucerne area and proceeds east and southeast, eventually terminating at Casper. The pipeline is used by several Big Horn Basin oil producers.

The second major pipeline within the study area is a 12-inch natural gas pipeline owned by Montana-Dakota Utilities Company. The line crosses only a small portion of the study area, entering the study area approximately six miles south-southeast of Manderson and proceeding north-northwest, crossing the Greybull River and leaving the study area. The pipeline originates in the Riverton Dome gas fields and is both a collection and distribution facility.

Powerlines Two major power transmission lines traverse the study area. Pacific Power and Light Company's 230 kv powerline enters the study area from the south from Riverton over the Owl Creek Mountains to Thermopolis. The line runs northwest from Thermopolis along State Highway 120 for approximately 25 miles, then north-northwest through badlands to Cody, paralleling State Highway 120. The powerline is used for local distribution of electricity.

The second major powerline is the Bureau of Reclamation's 115 kv line originating at Boysen Reservoir, crossing the Owl Creek Mountains into Thermopolis and running north through the study area generally paralleling the Big Horn River. The line crosses the Greybull River approxi-

mately two miles west of the town of Greybull and leaves the study area.

Both of the major powerlines mentioned were constructed using double wood poles ("H" style). The Bureau of Reclamation powerline is also used for distribution of electricity in other parts of Wyoming and in Montana.

Residential/Commercial/Industrial Major communities in the study area are the towns of Basin, Worland, Thermopolis, and Meeteetse. All of these communities lie on the fringes of the study area with most of Worland lying east of the Big Horn River, outside of the area. All of these communities are primarily agricultural trade centers. Only Worland has any major industries — a sugar beet refinery, meat packing plant, and soft drink bottling plant — all of which are dependent upon the agricultural economy of the region. These industries are all physically located outside of the study area.

Timber There are approximately 20,000 acres of commercial timber in the study area, most of which are located in the southwestern sector of the area within the Upper Grass Creek and Enos Creek drainages. There is a small sawmill operation located at the town of Grass Creek with little of the timber processed coming from within the study area.

Recreation Most recreation uses within the study area are extensive. Such uses include operation of off-road vehicles (four-wheel drive vehicles and motorcycles), hunting, rockhounding, and artifact collecting. (See Outdoor Recreation Values section later in this chapter.)

Plans — Controls — Zoning

A general land-use plan for the study area was prepared in 1971-72 by BLM. The land use recommendation for oil and gas activities was to "continue to allow exploration and development with practical stipulations to protect and rehabilitate the environment, coordinate protection and rehabilitation measures with other involved resources." The plan contains land use recommendations for all other resource activities in addition to oil and gas activities.

There are no area-wide comprehensive land use plans or other land use plans within the study area. Some of the communities within the area have implemented zoning within their municipal boundaries.

Suitability

The obvious aspect of suitability of lands for oil and gas leasing and, implicitly, production is whether or not the lands within the study area contain deposits of oil and gas. They do. Aside from that aspect of suitability there are others such as topographic, climatic, social, vegetative, fish and wildlife values, water, and drainage patterns. These factors all are limitations on suitability of lands for oil and gas production. Government policies and economics are the primary overriding factors on the above land use suitability factors. Present federal oil and gas policy requires maximum production of domestic oil and gas. The goal is energy self sufficiency. As to the oil companies producing the oil and gas, their goal is to produce oil and gas at minimum cost with a maximum return.

The majority of the lands within the study area, especially the federal lands and private grazing lands with federal mineral rights, are as suitable as any other lands for oil and gas production. The majority of the lands are unpopulated or sparsely populated, which means that most oil and gas activities in the area would have little if any direct impact on populated areas or ranch and farm homesteads or improvements. Oil and gas activities are generally a socially acceptable land use within the area.

Forage production on most of the federal lands and on the private and state grazing lands is low due to limited precipitation. The potential for other uses of these lands, such as agricultural, residential, commercial, and recreational, is limited, at least into the foreseeable future. Lack of water is the most significant factor.

Topography of the area varies from rolling plains and flat mesas to dissected badlands and mountain foothill regions. Difficulty of access varies with topography. Generally, vehicle access to most of the lands is possible with minor road construction and careful route selection on the rougher areas. With few perennial streams, expensive structures for bridges for stream crossings are not normally needed. There is little need for road construction and surfacing of roads except to and around developed oil and gas fields. Dust is more of a problem than mud.

Compatibility

Roads, drill sites, and oil field development on grazing or agricultural lands, and wildlife habitat takes those lands out of forage production. The change of use can be temporary or long term, especially if a producing field is discovered. The conflict with these uses is direct as to the lands occupied and used for oil and gas activities and facilities.

Oil and gas production facilities create visual impacts on the landscape. The character and values of scenic areas and other undeveloped landscapes are sometimes altered directly or indirectly from oil field and gas field development and from development of supporting facilities such as roads, pipelines, powerlines, and communication sites.

Water

Introduction

The Grass Creek area is made up of five large (greater than 125,000 acres) and six small (20,000 to 65,000 acres) watersheds that drain directly into the Big Horn River. The larger watersheds include Owl Creek, Cottonwood Creek, Gooseberry Creek, Fifteenmile Creek, and the Greybull River. The smaller watersheds include Coal Draw, Sand Draw, Little Gooseberry Creek, Fivemile Creek, Tenmile Creek, and Elk Creek. These drainages are illustrated on

Map 5. With the exception of Fifteenmile Creek, the larger watersheds have their headwaters in the Absaroka Mountains. These mountain streams flow eastward, rapidly dropping in elevation into the Big Horn Basin. Here they meander through the semi-arid rangeland until reaching the Big Horn River. All are perennial streams. The smaller watersheds and Fifteenmile Creek have their headwaters within the semi-arid rangeland of the basin. They are all ephemeral streams.

Annual precipitation in the higher elevations — generally above 6,800 feet — is greater than 14 inches. Here recharge is the greatest. In this area more permeable strata outcrop, alluviums consist of coarse grain material, and the vegetation is quite dense — all of which enhances infiltration. Evaporation rates are lower than those of the lower elevations. Runoff is high due to the volume of precipitation received and steep slope.

The largest part of the study area, which is below 6,200 feet, has an average annual precipitation of 6 to 10 inches. Recharge rates are low. Siltstone and shales outcrop over much of the land. Alluviums consist of fine grain material and the vegetation is sparse. Evaporation rates are high, more than twice the annual precipitation. Runoff is moderate to high in relation to the amount of precipitation received.

Water Quantity

Surface Water The Owl Creek watershed contains 135,000 acres within the southern part of the study area. (See Map 5.) A USGS stream gauge located in T. 43 N., R. 95 W., sec. 19, collected data from 1939 to 1969. Mean discharge for this period was 27.4 cfs (cubic feet per second). Mean annual instantaneous peak discharge was 737 cfs, generally occurring in May or June. Mean annual minimum discharge was 1.2 cfs. A composite hydrograph is illustrated below.

FIGURE 6—Hydrograph

Mean Monthly Discharge from Owl Creek
T. 43 N., R. 95 W., section 19 (1939-1969)

Month	Runoff (cfs)
Oct	9.1
Nov	12.2
Dec	12.2
Jan	11.7
Feb	17.5
Mar	23.0
Apr	26.2
May	50.2
Jun	109.4
Jul	36.0
Aug	11.9
Sept	9.4

Compilation of Surface Water Records, Missouri River Basin above Sioux City, Iowa, through 1950. USGS Water Supply Paper 1309, p. 415.

A comparison of the above information with data from two gauging stations upstream near Anchor Reservoir indicates that winter and early spring runoff from the lower elevations maintains streamflows from December through April. From May through October, most of the runoff is from the higher elevations generally outside the study area. There are no oil field waters discharged into Owl Creek.

The Cottonwood Creek watershed immediately north of Owl Creek contains 258,000 acres within the study area. (See Map 5.) The only stream gauge data were collected from 1941-45 at Winchester, T. 45 N., R. 94 W., sec. 17. The mean discharge was 35.4 cfs. Mean annual instantaneous peak discharge was 2,160 cfs. A minimum discharge of 0 cfs was observed each of the five years. A hydrograph of the five years of data is illustrated below. Because of the short period of record, the hydrograph may not represent a truly accurate picture of discharge over a long period of time.

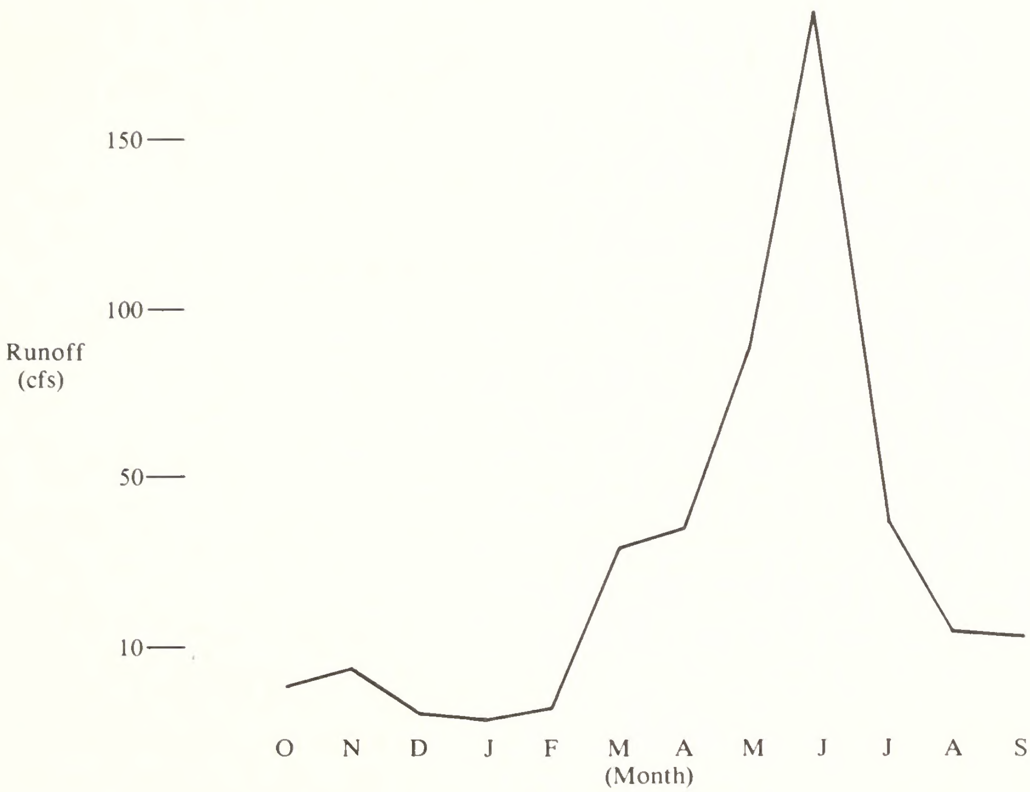
A total of 8.01 mgd (million gallons per day) or 12.39 cfs is discharged from oil fields into tributaries of Cottonwood.

months produce some runoff which sustains streamflow. Also, groundwater seeps into the creek, helping to maintain late fall and winter streamflow. During March and April, most of the snowpack in this area melts, producing a large volume of runoff. By May, nearly all of the runoff comes from the higher elevations above the Dickie station. Runoff from the higher elevations continues throughout June into early July. At this time, nearly all the snowpack has melted. Temporarily stored groundwater from the spring melt coupled with thunderstorm activity sustains streamflows during July and into early August.

A total of 0.47 mgd or 0.73 cfs is discharged from oil fields into tributaries of Gooseberry Creek.

FIGURE 7—Hydrograph

Mean Monthly Discharge from Cottonwood Creek
T. 45 N., R. 94 W., sec. 17 (1941-1945)



Month	Runoff (cfs)
Oct	6.3
Nov	7.5
Dec	3.8
Jan	2.0
Feb	3.9
Mar	30.0
Apr	38.0
May	84.1
Jun	182.5
Jul	42.1
Aug	13.0
Sept	11.1

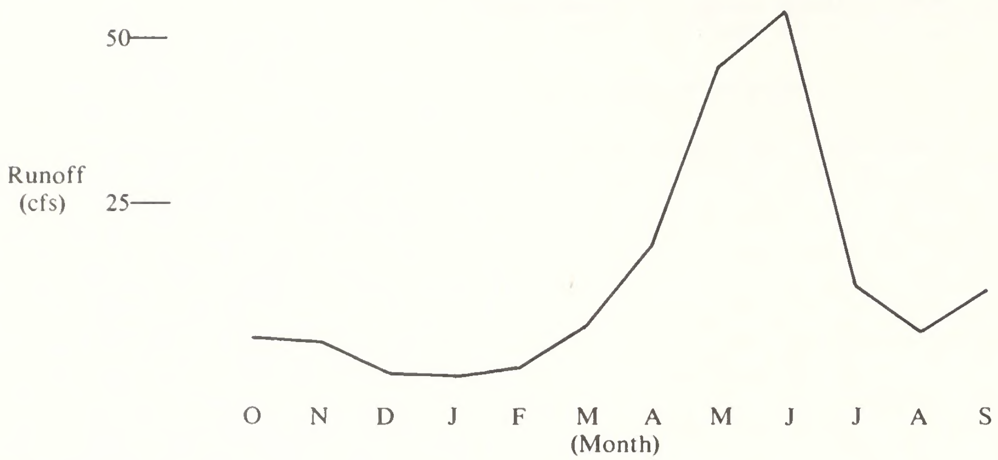
Compilation of Surface Water Records, Missouri River Basin above Sioux City, Iowa, through 1950. USGS Water Supply Paper 1309, p. 415.

The Gooseberry Creek watershed contains 210,000 acres within the study area. (See Map 5.) Stream gauge data were collected at Dickie, T. 47 N., R. 99 W., sec. 32, from 1957 to 1974. Mean discharge was 13.7 cfs. The mean annual instantaneous peak discharge was 327 cfs, generally occurring during May or June. Minimum annual discharge was 0.9 cfs and occurred during the winter and late summer months. A hydrograph of the streamflow is presented on the following page.

Stream gauge data at the mouth of Gooseberry, T. 46 N., R. 93 W., sec. 30, is available from the 1941 to 1953 period. Mean discharge was 13.7 cfs. A comparison of the two stations indicated a similar discharge pattern to that which was found on Owl Creek. Periodic warm spells downstream from Dickie during the late fall and winter

FIGURE 8—Hydrograph

Mean Monthly Discharge—Gooseberry Creek at Dickie
T. 47 N., R. 99 W., sec. 32 (1957-1974)



Month	Runoff (cfs)
Oct	5.1
Nov	4.5
Dec	2.5
Jan	1.8
Feb	3.2
Mar	5.9
Apr	17.1
May	45.0
Jun	52.1
Jul	12.9
Aug	6.0
Sept	9.0

Water Resource Data for Wyoming, Part I, Surface Water Records, U.S. Dept. of Interior, Geological Survey (1957-1974).

FIGURE 9—Hydrograph

Mean Monthly Discharge from Gooseberry Creek
T. 46 N., R. 93 W., sec. 30 (1941-1953)

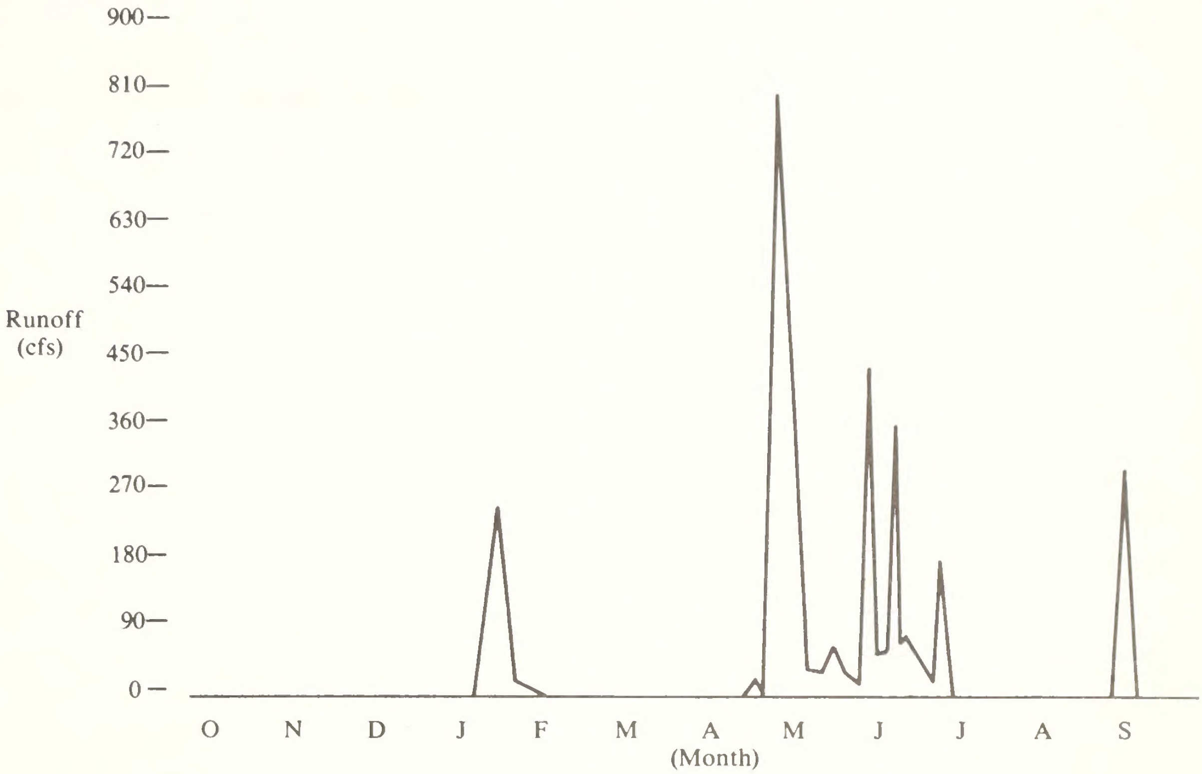
Month	Runoff (cfs)
Oct	5.9
Nov	7.4
Dec	5.2
Jan	2.1
Feb	2.6
Mar	20.5
Apr	25.7
May	34.4
Jun	44.2
Jul	10.0
Aug	2.9
Sept	4.2

Compilation of Surface Water Records, Missouri River Basin above Sioux City, Iowa, through 1950. USGS Water Supply Papers 1309, pp. 417, 418.

The Fifteenmile Creek drainage is the largest in the study area, containing 332,000 acres. This ephemeral drainage generally produces high intensity, short duration runoff. The exception would be during the spring when any winter snow accumulation produces a continued runoff for up to a month, or during an exceptionally wet spring. The Fifteenmile gauging station, located in T. 47 N., R. 93 W., sec. 27, was operated from 1951-1972. Annual mean instantaneous peak discharge was 1,668 cfs. The mean discharge was 11.0 cfs. A typical hydrograph is illustrated below.

FIGURE 10—Hydrograph

Mean Monthly Discharge from Fifteenmile Creek Near Worland
T. 47 N., R. 93 W., sec. 27 (1963)



Water Resource Data for Wyoming, Part I, Surface Water Records, U.S. Department of the Interior, Geological Survey (1963).

The Fifteenmile Creek drainage is a high sediment producer. Regression analyses were run on stream gauge data collected from 1960-1972. A comparison of the streamflow with the suspended sediment yield in tons per day indicated that 83 percent of the variation in suspended sediment can be accounted for by a variation in streamflow. This provides a useful tool of estimating the sediment yield based on streamflow. The equation $y = 226.04 + 144.27x$ expresses this relationship. Where y = suspended sediment yield in tons per day, x = streamflow in cfs.

For the 12 years of data, the mean discharge was 15.82 cfs. The mean discharge of suspended sediment was 2,103.07 tons per day.

The Greybull River watershed contains 714,000 acres, of which 139,000 acres are located within the study area. A gauging station is located near Basin, T. 51 N., R. 94 W., sec. 8. The river is the second largest within the area with a mean discharge of 245 cfs. However, an insignificant proportion of this water is produced in the study area. A total of .004 mgd or .006 cfs is discharged into the Wood River from oil and gas wells.

No stream gauge data has been collected on the six smaller ephemeral watersheds which drain directly into the Big Horn River. These drainages, under normal conditions, discharge water only after localized precipitation events or when any winter snow accumulation melts. A large amount of sediment is to be expected from these runoffs.

Oil field waters discharged into Coal Draw total 0.63 mgd or 0.97 cfs and those into Sand Draw total 0.04 mgd or 0.06 cfs.

Groundwater[1] Groundwater exists in all of the geologic units in the study area. Yields and quality of subsurface waters vary from one lithologic unit to the next and may even vary within a particular lithologic unit. The following is a summary of the geologic units of the area.

Unconsolidated flood plain deposits, terrace deposits, landslide debris, and glacial deposits:

The permeability of these deposits is extremely variable, depending upon sorting and grain size. Flood plain and terrace deposits composed of the fine grain material exposed over much of the Basin will not yield large supplies of water. Yields of two to eight gallons per minute (gpm) are common at depths of 10 to 100 feet.

Flood plain and terrace deposits composed of the larger grain materials are associated with streams which have their headwaters in the mountains. Yields of 15 to 70 gpm or greater are common. The yield is limited by the generally thin water bearing strata.

Landslide deposits and glacial deposits are composed of material low in permeability. Up to four gpm would be expected.

Volcanic sediments:

Water-bearing properties differ greatly because of the diverse lithology. Yields from the volcanics probably vary from 5 to 30 gpm.

Tatman, Willwood, Fort Union, Lance, Meeteetse, and Mesaverde Formations:

These tertiary and upper Cretaceous formations consist of inter-bedded shales, mudstone, marl, sandstones with some minor coal, and conglomerate lenses. The discontinuous sandstone beds are the only significant water producing zones.

[1]Information for the groundwater section was taken from "Water Resources of the Big Horn Basin, Northwestern Wyoming," Dept. of Interior, U.S. Geological Survey, prepared by Marlin E. Lowry, Hugh W. Lowham, and Gregory C. Lines.

Frontier Formation, Mowry and Thermopolis shales (Mesozoic):

The Frontier contains somewhat less than 50 percent sandstone which supplies a dependable source of water.

The Mowry shale is brittle and fractures when subjected to stress, yielding water to wells and springs.

The Muddy sandstone member of the Thermopolis shale is a dependable source of water.

Cloverly, Morrison, Sundance, Gypsum Spring, Chugwater Formations:

These Mesozoic formations consist of bentonite mudstone, sandstones, limestones, siltstones, massive gypsum, and shales. The sandstones in the Cloverly, Morrison, and Sundance are the best sources of water. Large scale solution openings occur in the gypsum beds of the Gypsum Springs and Chugwater Formations from which the potential for large yields exists.

Park City, Tensleep and Madison Formations (Paleozoic):

These formations consist of dolomite, massive sandstone, and massive limestone. Permeability is very good with yields from 200 to greater than 1,000 gpm.

Three Forks, Jefferson, and Flathead Sandstone Formations (Paleozoic):

The formations consist of limestone, siltstone, dolomite, and sandstone. Yields from these formations are somewhat less than from the Park City, Tensleep, or Madison.

Existing oil and gas production has affected the natural distribution of surface and groundwaters. There are large quantities of water mixed together with the oil in the ground. When this fluid is brought to the surface, the water is separated from the oil and disposed of. A total of 16.72 mgd (million gallons per day) of water is produced in the study area. Of this, 6.83 mgd are reinjected and 9.89 mgd are discharged into drainages. Table 4 breaks down the produced waters by fields.

TABLE 4
Produced, Reinjected and Discharged Oil Field Waters
(millions of gallons per day discharged)

Field	Produced water/mgd	Reinjected water/mgd	Discharged water/mgd	
Little Buffalo Basin	2.64	2.18	0.46	
Hamilton Dome	9.17	1.04	8.13	
Grass Creek	3.61	3.61	0	
Golden Eagle	0.58	0	0.58	
Gebo	0.55	0	0.55	
Little Sand Draw	0.04	0	0.04	
Waugh	0.04	0	0.04	
King Dome	0.04	0	0.04	
Prospect Creek	0.01	0	0.01	evaporation and
Enos Creek	0.01	0	0.01	infiltration
South Sunshine	0.01	0	0.01	
North Sunshine, Skelton Dome, Aspen Creek, and Gooseberry	0.02	0	0.02	
Totals	16.72	6.83	*9.89	

*This total is roughly five percent of natural annual streamflow.
Data supplied by oil field operators and USGS Conservation Division.

The discharged water supplements natural streamflows. In some cases small ephemeral drainages flow year round with the addition of the discharge water. Roughly five percent of the annual runoff can be attributed to produced oil field waters. Discharged water accounts for less than 0.01 percent of the total groundwater supply.

Much of the discharged water is presently used for irrigation and livestock. Once the discharge water enters a natural draw or drainage, it is considered part of the general supply of the drainage, subject to all valid appropriation in the drainage and controlled by the state. It is, therefore, impossible to determine exactly who uses how much water and for what purpose. There are, however, 4.1 mgd diverted directly from the Hamilton Dome field for irrigation. It is estimated that during the summer months more than 90 percent of all discharged water is put to beneficial agricultural and livestock watering use. This figure drops to less than 10 percent during the winter months.

Water Quality

Surface Water Four water quality samples taken at the mouth of Owl Creek were analyzed for the city of Worland. These readings are displayed in Table 5.

TABLE 5
Water Quality—Mouth of Owl Creek

Tests	Units	Nov 1973	Jan 1974	April 1974	March 1975
Carbonate	mg/l	48.0	0.0	0.0	0.0
Bicarbonate	mg/l	250.0	342.0	377.0	350.0
Chloride	mg/l	14.0	19.0	24.0	23.0
Nitrate	mg/l	0.7	1.4	5.0	1.1
TDS (Total dissolved solids)	mg/l	1710.0	2080.0	2192.0	1930.0
Sulfate	mg/l	990.0	1230.0	1290.0	1100.0
Sodium	mg/l	230.0	274.0	289.0	260.0
Percent sodium	—	39.0	46.0	37.0	—
Potassium	mg/l	7.0	4.9	4.4	7.9
Calcium	mg/l	170.0	206.0	210.0	180.0
Magnesium	mg/l	82.0	72.0	128.0	100.0
Fluoride	mg/l	1.2	0.8	0.9	0.5
pH	—	8.7	8.3	8.3	7.9

Analysis done by Wyoming Dept. of Agriculture, Division of Laboratories, P.O. Box 3228, Laramie, WY 82070.

A suspended sediment sample was taken by USGS near the mouth of Owl Creek on May 20, 1965. The discharge was 20 cfs and suspended sediment concentration was 1680 mg/l. On September 17, 1974, a conductivity reading (below Anchor Reservoir) of 150 micromhos was recorded. Discharge was 8.8 cfs and the water temperature was 9°C.

There is some existing water quality data on Cottonwood Creek. Two samples were analyzed for the purpose of this study. Table 6 illustrates the test results.

TABLE 6
Water Quality—Cottonwood Creek

Date Sampled:		**4/9/76**	**4/9/76**	
Sample No.:		**No. 1**	**No. 2**	
Tests	**Units**	**Cottonwood Cr. T45N R96W sec 19**	**Cottonwood Cr. T44N R99W sec 23**	**Percent Change**
Carbonate	mg/l	0.00	0.00	
Bicarbonate	mg/l	375.00	183.00	+ 105
Chloride	mg/l	236.00	101.00	+ 134
Nitrate	mg/l	1.00	3.00	- 200
Boron	mg/l	0.77	.11	+ 600
TDS (Total dissolved solids)	mg/l	1994.00	293.00	+ 581
TSS (Total suspended sediments)	mg/l	334.00	119.00	+ 181
Sulfate	mg/l	900.00	45.00	+ 1900
Sodium	mg/l	420.00	74.00	+ 468
Potassium	mg/l	70.50	4.40	+ 1502
Calcium	mg/l	175.00	25.00	+ 600
Magnesium	mg/l	82.50	5.00	+ 1550
Oil & Grease & other organic materials	mg/l	4.40	5.40	- 19

Location of samples are point illustrated on Map 5.
Water samples collected and analyzed by Northwest Analytical Laboratory, Powell, Wyoming.

Sample 1 was taken downstream from Hamilton Dome prior to the point of confluence with Grass Creek. Sample 2 was taken upstream from any oil activity. (See Map 5.) No discharge measurements were made at the time. Streamflow was low. There is a definite reduction in water quality between the two sample points. Bicarbonate, chloride, boron, total dissolved solids, sulfate, sodium, potassium, calcium, and magnesium concentrations are all more than twice as great at the downstream sample point. These constituents are in high concentration in the oil field discharge water. Nitrate and oil and grease concentrations, on the other hand, were lower at the downstream sample point.

Water quality data was also collected periodically from 1973-1975, by the City of Worland, at the mouth of Cottonwood Creek. Results are shown on Table 7.

TABLE 7
Water Quality—Mouth of Cottonwood Creek

Tests	Units	Nov 1973	Jan 1974	March 1974	March 1975
Carbonate	mg/l	12.0	0.0	0.0	0.0
Bicarbonate	mg/l	354.0	598.0	380.0	480.0
Chloride	mg/l	270.0	424.0	309.0	355.0
Nitrate	mg/l	0.5	2.1	6.1	1.1
TDS (Total Dissolved Solids)	mg/l	2520.0	3680.0	2624.0	2910.0
Sulfate	mg/l	1200.0	1740.0	1240.0	1330.0
Sodium	mg/l	480.0	742.0	505.0	550.0
Percent sodium	—	55.0	60.0	55.0	—
Potassium	mg/l	37.0	35.0	33.0	42.0
Calcium	mg/l	130.0	223.0	179.0	170.0
Magnesium	mg/l	100.0	110.0	99.0	130.0
Flouride	mg/l	1.8	1.9	1.4	1.1
pH	—	8.4	8.2	8.1	7.9

Analysis done by Wyoming Dept. of Agriculture, Division of Laboratories, P.O. Box 3228, Laramie, WY 82070.

TABLE 8
Sedimentation—Mouth of Cottonwood Creek

Point of Sample	Date	Dis. (cfs)	Sus. Sed. mg/l	Tons/ day
Winchester— T45N R94W sec. 17	6/26/65	350	73,600	69,000
Winchester— T45N R94W sec. 17	3/10/66	37	4,590	459
T45N R96W sec. 19	4/9/76	—	334	—
T44N R99W sec. 23	4/9/76	—	119	—

Analysis done by Wyoming Dept. of Agriculture, Division of Laboratories, P.O. Box 3228, Laramie, WY 82070.

Sediment Data was collected at the mouth of Cottonwood Creek in June 1965 and March 1966. Results are illustrated in Table 8.

This limited data suggests what is generally known concerning runoff and suspended sediment relationships. High runoff produces a high concentration of suspended sediment as is illustrated with the June 1965 sample. The limited data, however, are not adequate to establish high and low suspended sediment limits or relate them to streamflow.

Grass Creek is a tributary of Cottonwood Creek. (See Map 5.) Two water quality samples were collected. Results are illustrated in Table 9.

Irrigation, construction, oil and gas activity, and the natural environment contribute to water quality degradation in Grass Creek. Irrigation is thought to be the most

TABLE 9
Water Quality—Grass Creek

Date Sampled:		**4/8/76**	**4/8/76**	
Sample No.:		**(No. 9)**	**(No. 10)**	
Tests	**Units**	**Grass Creek T45N R96W sec 8**	**Grass Creek T45N R100W sec 16**	**Percent Change**
Carbonate	mg/l	0.00	0.00	
Bicarbonate	mg/l	366.00	226.00	+62
Chloride	mg/l	48.00	3.80	+1163
Nitrate	mg/l	8.00	5.00	+60
Boron	mg/l	0.44	1.40	-69
Total Dissolved Solids	mg/l	980.00	326.00	+201
Total Suspended Sediments	mg/l	1816.00	284.00	+539
Sulfate	mg/l	380.00	35.00	+986
Sodium	mg/l	218.00	48.00	+354
Potassium	mg/l	10.30	9.30	-11
Calcium	mg/l	75.00	30.00	+150
Magnesium	mg/l	65.00	14.00	+364
Oil and Grease	mg/l	1.00		

Locations of the samples are illustrated on Map 5.
Analysis done by Northwest Laboratory, Powell, Wyoming.

TABLE 10
Water Quality—Gooseberry Creek

Date: 4/8/76						
Sample No.:		**No. 5**	**No. 6**	**No. 7**	**No. 8**	
Tests	**Units**	**T46N R93W**	**T47N R97W**	**T46N R99W**	**T46N R101W**	**Percent Change**
Carbonate	mg/l	0.00	0.00	0.00	0.00	
Bicarbonate	mg/l	412.00	244.00	195.00	177.00	+133
Chlorides	mg/l	48.00	4.90	4.40	3.10	+1448
Nitrates	mg/l	6.00	6.00	12.00	3.00	+100
Boron	mg/l	0.11	0.33	0.11	1.32	-92
TDS	mg/l	2336.00	360.00	386.00	216.00	+981
TSS	mg/l	2084.00	166.00	1864.00	90.00	+2216
Sulfate	mg/l	1150.00	133.00	140.00	25.00	+4500
Sodium	mg/l	620.00	48.00	47.00	34.00	+1724
Potassium	mg/l	17.50	6.80	7.70	3.70	+373
Calcium	mg/l	125.00	44.60	42.00	28.20	+343
Magnesium	mg/l	137.50	25.00	25.00	14.00	+882
Oil & Grease	mg/l	2.20	—	—	—	—

Analysis done by Northwest Laboratory, Powell, Wyoming.

significant contributor. No quantification of the degree of degradation has been made.

There are no oil field permits issued for discharge into Grass Creek. The stream, however, does flow through the Grass Creek oil field. The reduction in water quality between the two sample points is the result of a variety of conditions. The natural environment of the drainage basin, coupled with man's activities (grazing, mineral exploration, recreation, and agriculture) reduce the quality of the water. The limited data available on Grass Creek is insufficient to present the total water quality picture.

The Gooseberry Creek watershed was sampled at four points. (See Map 5.) The results are presented in Table 10.

According to these samples, water quality is reduced the further downstream the sample. This is most evident between Sample No. 6 and Sample No. 5. There is a considerable amount of irrigated agriculture between these sample points.

Water quality data were also collected at the mouth of Gooseberry Creek. Suspended sediment data were available for three years.

TABLE 11
Water Quality—Mouth of Gooseberry Creek

Tests	Units	Nov 1973	Jan 1974	Mar 1974	Mar 1975	May 1975
Carbonate	mg/l	43.0	0.0	0.0	0.0	0.0
Bicarbonate	mg/l	403.0	769.0	404.0	620.0	510.0
Chloride	mg/l	47.0	95.0	67.0	63.0	130.0
Nitrate	mg/l	1.1	2.2	7.3	1.5	1.0
TDS	mg/l	2550.0	5500.0	3112.0	3900.0	6570.0
Sulfate	mg/l	1470.0	3320.0	1880.0	2300.0	4600.0
Sodium	mg/l	490.0	1120.0	598.0	860.0	1600.0
Percent sodium	—	57.0	63.0	53.0	—	—
Potassium	mg/l	9.3	6.7	9.3	6.3	13.0
Calcium	mg/l	103.0	190.0	142.0	160.0	190.0
Magnesium	mg/l	130.0	228.0	190.0	180.0	250.0
Flouride	mg/l	1.6	2.7	1.0	1.3	1.3
pH	—	8.7	8.2	8.3	8.1	8.3

Analysis done by Wyoming Dept. of Agriculture, Division of Laboratories, P.O. Box 3228, Laramie, WY 82070.

TABLE 12
Monthly Summary
Streamflow and Sediment Data—Gooseberry Creek at Pulliam
T. 46 N., R. 93 W., sec. 30

1951	**March**	**April**	**May**	**June**	
Streamflow cfs	3.1	1.0	0.3	1.2	
Suspended sediment concentration mg/l	8,970	651	24.5	332	
1952	**March**	**April**	**May**	**June**	**Oct**
Streamflow cfs	2.5	37.1	77.2	13.8	0.33
Suspended sediment concentration mg/l	758	11,678	7,596	1,211	33
1953	**March**	**April**	**May**	**June**	
Streamflow cfs	2.9	7.5	0.69	0.53	
Suspended sediment concentration mg/l	424	728	210	66	

Data from USGS (personal contact with Stan Druse).

TABLE 13
Water Quality—Enos Creek

Tests	Units	Enos Creek No. 3 T46N R99W	Dickie "V" (Enos) No. 4 T47N R100W	Percent Change
Carbonate	mg/l	0.00	0.00	
Bicarbonate	mg/l	195.00	207.00	-6
Chlorides	mg/l	4.40	5.00	-12
Nitrates	mg/l	14.00	10.00	+40
Boron	mg/l	0.33	0.33	0
Total dissolved solids	mg/l	430.00	244.00	+76
Total suspended sediments	mg/l	1132.00	632.00	+79
Sulfates	mg/l	116.00	35.00	+231
Sodium	mg/l	45.00	36.00	+25
Potassium	mg/l	7.30	11.00	-34
Calcium	mg/l	39.10	27.00	+45
Magnesium	mg/l	24.00	16.50	+45

Analysis done by Northwest Laboratory, Powell, Wyoming.

Two samples were taken from Enos Creek, a tributary of Gooseberry Creek. (See Map 5.) Suspended sediment and total dissolved solids increased between the two sample points.

Water quality data have been collected on the Greybull River. The study area, however, contributes little water to this river and has little effect on water quality in the river. Analysis of the river, therefore, will not be included in this study.

Some surface waters in the planning unit exist only as a direct result of oil and gas activities. They are a result of the discharge on the surface of water which is produced with oil.

Discharged water is regulated by the State Department of Environmental Quality, Water Resource Division. The department, in conjunction with the U.S. Environmental Protection Agency, is responsible for establishing water quality criteria for produced waters that are discharged. Below is a copy of "Criteria for Produced Water in Wyoming."

CRITERIA FOR PRODUCED WATER IN WYOMING

Developed by: Wyoming Department of Health and Social Services
Wyoming Department of Agriculture
U.S. Environmental Protection Agency

1. All produced water discharges which are documented as being used for irrigation, livestock or wildlife watering shall be allowed to continue to discharge, except in those cases where such discharges cause violation of water quality standards of the State of Wyoming.
2. In those cases where it is not documented that the produced water is being used for irrigation, livestock or wildlife watering, the discharge will be allowed only when it meets the following criteria.

Parameter	Maximum Permissible Limit at Point of Discharge
a. Chlorides	2,000 mg/l
b. Total Dissolved Solids	Below 5,000 mg/l—acceptable; 5,000 to 7,500 mg/l—consideration will be made of beneficial use, individual chemical constituents, and nature of the drainage area. Above 7,500 mg/l—acceptable only if beneficial use is shown.
c. Magnesium Sulfate plus Sodium Sulfate	3,000 mg/l
d. Oil and Grease	10 mg/l
e. Toxic Substances	Free from toxic substances in concentrations or combinations which are toxic to human, animal, plant, or aquatic life.

In addition to the above limits, the following shall apply at the point where a produced water discharge enters a live water body:

f. Chemical Oxygen Demand	100 mg/l
g. Temperature	85 degrees F.
h. pH	6.5-8.5

In addition to the above limits, the following shall apply to discharges which are of a spread flow type in which damage to surface vegetation could occur:

i. Sodium Ion Concentration	50% of all application constituents

These general criteria are used to establish specific water quality parameters for each individual field. Depending upon the amount of discharge, the receiving drainage, and general availability of surface water, specific parameters are established to maintain water quality. Oil field operators are required to submit sample data every three to six months to the Department of Environmental Quality. If the water does not meet DEQ requirements, the oil fields must improve their treatment of the water. In the case where there are continued violations, fines may be imposed.

Water quality samples were taken from various oil (fields at the point of discharge into a drainage. These samples were analyzed by Northwest Analytical Laboratory. The results are presented in Table 13a.

The chemical quality of the discharge water is not static and may change on a day-to-day basis. However, the above test results give an indication as to general quality of the discharged water.

None of the sampled discharged water could be considered fit for human consumption. Sulfates and total dissolved solids far exceed 1962 Public Health Service recommendations for drinking water. In addition, oil and grease, chlorides, and manganese exceed public health recommendations at some of the sites sampled. Odor and taste would also be prohibitive at some sites.

Discharge water is presently used for irrigation, the effect of which is discussed in the soils section.

Discharge water is also used for livestock and wildlife watering. If the total dissolved solids (TDS) are below 7,000 mg/l, the water is generally considered suitable for beef cattle. However, concentrations well below the 7,000 mg/l limit are best. Discharged waters tested had TDS below 4,000 mg/l. The wildlife use of discharge water is discussed in the wildlife section.

There are no known industrial uses of discharged water.

Groundwater[1]

Unconsolidated flood plain deposits, terrace deposits, landslide debris, and glacial deposits:

The water varies in chemical composition and is generally marginal for human consumption and suitable for

[1]Information for the groundwater section was taken from "Water Resources for the Big Horn Basin, Northwestern Wyoming," Dept. of Interior, U.S. Geological Survey, prepared by Marlin E. Lowry, Hugh W. Lowham, and Gregory C. Lines.

TABLE 13a
Water Quality Data from Selected Oil Fields

Tests	Units	Waugh	Lt. Sand Draw	Hamilton Dome Ashland	Hamilton Dome At. Rich.	Golden Eagle	Gebo
Oil and Grease	mg/l	3.30	8.00	<1.00	<1.00	24.90	34.00
Carbonate	mg/l	0.00	0.00	0.00	0.00	90.00	0.00
Bicarbonate	mg/l	823.00	713.00	744.00	1327.00	336.00	610.00
Chloride	mg/l	395.00	197.00	543.00	526.00	373.00	406.00
Boron	mg/l	3.60	2.00	4.10	2.20	6.90	6.10
Total dissolved solids	mg/l	2885.00	3206.00	3474.00	3645.00	3513.00	3259.00
Sulfate	mg/l	1050.00	1400.00	1100.00	850.00	1600.00	1250.00
Sodium	ppm	367.00	327.00	553.00	473.00	740.00	537.00
Potassium	ppm	115.00	91.00	105.00	108.00	77.00	53.70
Calcium	ppm	340.00	445.00	391.00	476.00	255.00	448.00
Magnesium	ppm	95.00	80.00	112.00	102.00	74.00	71.00
Copper	ppm	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	ppm	<0.10	<0.10	<0.20	<0.10	<0.30	<0.20
Manganese	ppm	<0.02	<0.02	<0.38	<0.12	<0.04	<0.02
Silver	ppm	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Strontium	ppm	27.00	26.00	17.00	21.00	23.00	24.00
Tin	ppm	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Barium	ppm	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Bromine	mg/l	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Iodine	ug/l	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Water temp.	°C	18°	11°	—	—	14°	32.5°

Analysis done by Northwest Analytical Laboratory, Powell, Wyoming.

livestock and wildlife. Coarse-grained flood plain and terrace deposits are generally suitable for human consumption, irrigation, livestock, and wildlife, as well as most industrial uses.

Volcanic Sediments:

These waters are probably suitable for human consumption, livestock, and wildlife. No water from these strata was analyzed.

Tatman, Willwood, Fort Union, Lance, Meeteetse, and Mesaverde Formations:

Waters from these formations would only infrequently be suitable for human consumption. They are frequently used for watering livestock and for wildlife.

Frontier Formation, Mowry, and Thermopolis Shale:

These waters are usually suitable for irrigation, livestock, and wildlife. The Frontier is also oil producing.

Cloverly, Morrison, Sundance, Gypsum Springs, and Chugwater Formations:

Water in the upper sandstone beds is suitable for livestock, and wildlife. The lower sections may supply suitable water for livestock and wildlife. However, high temperature springs discharging from these sections produce highly mineralized waters.

Park City, Tensleep, Madison, Three Forks, Jefferson, and Flathead Formations:

Water quality varies but is generally good, suitable for human consumption, irrigation, livestock, wildlife, and some industrial use.

Plants

Aquatic

Habitat for aquatic vegetation consists of the Big Horn River, numerous irrigation and drainage ditches, live streams and untold numbers of small reservoirs, ponds, natural seeps, and springs.

Moss and algae are present in the Big Horn River and many of the ditches, canals, and drain sloughs. These species are particularly noticeable in the summertime. Phytoplankton undoubtedly exists, but has not been identified.

A variety of vascular aquatic plants occurs in sumps, swampy and semi-wet areas throughout the area. The more important species are: narrow-leaf cattail (*Typha angustifolia*), pondweed (*Potamogeton* spp.), rushes (*Juncus* spp.), bur-reed (*Sparganium* spp.), and arrowgrass (*Triglochin* spp.). Many of the swampy areas are created by irrigation waste water of varying salinity and alkalinity and containing a variety of fertilizer and pesticide residues. Aquatics are intolerant of excessive amounts of these residues and to petroleum residues, sedimentation, and high turbidities.

Terrestrial

The terrestrial vegetation of the area is a complex series of plant association communities. The location and distribution of these associations are a direct reflection of several natural factors including soils, pH, available moisture, air, and soil temperatures. These factors are, in turn, reflections of the geology, topography, and weather of the area.

Five major vegetation association zones have been identified in the study area. These correlate generally with elevation and precipitation factors. (See Map 6.) In an area as large and diverse as this, it is not possible or practical to describe the many intra-association divergencies and complexities. The changes between each zone are gradual, resulting in transition areas that are often several miles wide. It is not uncommon to find plant communities from one zone located well within the geographic boundaries of an adjoining zone.

The vegetation zone associations are delineated on Map 6 and discussed in the text. Fisser lists over 160 species of shrubs, grasses, and forbs occurring in the Big Horn Basin (University of Wyoming, 1964). In addition, several species of trees are found on selected sites in the study area. A partial list of the more important plants is included in the appendix.

Zone I: Desert Shrub Association This zone is semi-arid native rangeland typically classified as "winter sheep range"—a description indicative of the vegetative cover. Generally the area fits the description of the intermountain shrub region. The area covered by this zone is a rough triangle bounded on the southwest by Fifteenmile Creek and by the Big Horn and Greybull Rivers on the east and north. Elevations range from 3,500 to 4,500 feet and annual precipitation from four to seven inches.

The vegetation consists of open, sparse stands of low or dwarf shrub species. The dominant plant is Nuttalls saltbush (*Atriplex nuttallii*) which occurs in pure stands or mixed with other shrubs and grasses, depending upon individual site conditions. Important secondary components include such shrubs as bud sage, winterfat, and shadscale. On some of the better, well-drained sites a few remnants of desirable grasses such as western wheatgrass and Indian ricegrass remain. Less desirable species include rabbitbrush, halogeton, Russian thistle, prickly pear cactus, cheatgrass, squirrel tail, blue grama, and red three-awn.

Most species in this zone tend to be low growing, shallow-rooted and adapted to the low precipitation and the poorly developed alkaline soils of the area. Most of the area shows signs of heavy grazing in the past. Only remnants of desirable grasses remain; less desirable species have replaced them. Vigor of the desirable browse species is less than optimum, also due to heavy use by grazing animals.

Vegetation condition varies from poor to good with most areas rating in the poor to fair categories. Extensive areas of badland formations have no vegetative cover and are classified as barren.

The river bottoms along the Greybull and Big Horn Rivers are exceptions to the norm for this zone. Much of this area is farmed or has been cleared and irrigated. The native vegetation here consists of cottonwoods, willows, greasewood with understories of saltgrass, wheatgrasses, and bluegrasses depending on the water table and soil conditions.

Zone II: Desert Shrub—Grass Association This is actually a transition zone between Zones I and III. Annual moisture is in the seven-to-eight-inch belt and elevations are generally between 4,000 to 5,000 feet above sea level. Plant species are similar to Zone I, but density and relative composition are different.

Sagebrush is co-dominant with saltbush and blue grama becomes much more abundant. In some respects blue grama covers more actual ground area than the other species. Rabbitbrush, needlegrass, and ryegrass are minor species along with the wheatgrasses. Disturbed areas show signs of slow recovery with less desirable species such as rabbitbrush, pepperweed, and Russian thistle dominating these sites. Forage species, although more numerous than in Zone I, are generally in poorer vigor and condition due to grazing pressure. Range conditions are fair to poor. The high incidence of cactus is an indicator of unfavorable vegetation condition and trend. Cactus is an "invader" species that spreads and thickens as the more desirable plants are removed.

As in Zone I, the major stream bottoms support some cottonwood and willow trees. Brush is usually quite tall and thick, tending to be sagebrush or greasewood, depending on the salinity of the soil. Ryegrasses, cheatgrass, and saltgrasses usually flourish on these sites.

Zone III: Sagebrush—Grama Association This zone was probably originally more like the next higher zone (Zone IV), but years of heavy grazing pressure have replaced much of the wheatgrasses with the less palatable blue grama grass.

Elevations vary from 4,500 to 6,000 feet and annual moisture is in the eight-to-nine-inch range. Soils are deeper, better drained, and less saline. Big sagebrush and rabbitbrush are the dominant shrub species. Blue grama is the most abundant grass species, but needlegrasses and wheatgrasses are also present in significant amounts. Cactus and Russian thistle are abundant on disturbed or overgrazed sites. The poisonous larkspur is also widespread and is often a problem during the spring moisture season.

Utah juniper (*Juniperus osteosperma*) also occurs in narrow bands along rim rock areas, ridge crests, and rocky talus slopes. The lower portions of the major drainages (Gooseberry Creek, Grass Creek, and Cottonwood Creek) are similar to those described in Zones I and II.

Zone IV: Sagebrush-Wheatgrass Association This zone, situated in the 9-to-12-inch precipitation zone and between 5,500 and 6,500 feet elevation, is basically steep to rolling foothills. The rough terrain results in a variety of different sites and thereby a complexity in vegetation types and relationships. North and east facing slopes support dense stands of sagebrush, bluebunch, wheatgrass, occasional patches of Idaho fescue, and a variety of forbs and flowering plants such as lupine, yarrow, and penstemon. In contrast, south and west exposures have shallower,

dryer soils, and the vegetation is less dense and lower growing. Sagebrush, bluebunch wheatgrass, threadleaf sedge (*Carex filifolia*), and junegrass (*Koleria cristata*) are the dominants. Other plants include phlox, paintbrush, needlegrass, larkspur, and balsamroot.

Some ridgetops and rocky outcrop areas support a mixture of Utah juniper and limber pine (*Pinus flexilus*) and occasional stands of bitterbrush (*Purshia tridentata*).

In the narrow, smaller drainage bottoms, the vegetation is usually the same as on the surrounding hillsides. Wider drainages, particularly those having live streams, are usually lined with cottonwood, willow, and large sagebrush. These areas are usually heavily grazed and the herbaceous vegetation consists of bluegrasses (*Poa* spp.), ryegrass, thistle, and a variety of weedy forbs. Small wet meadow areas occur as a mixture of bentgrass, bluegrasses, sedges, dandelion, and wild iris.

Vegetation conditions vary from excellent to poor, depending upon the grazing pressure. Areas close to water and not too steep are usually well used. Conversely, steep sites and unwatered areas are lightly grazed and in good condition. Vegetation in this zone recovers more quickly from disturbance. Disturbed areas are usually quickly covered with cheatgrass, thistle, and a variety of forbs that give soil protection. Revegetation and recovery is quicker than in the more arid zones.

Zone V: Mountain Forest-Sagebrush-Grass Association This association occurs above the 6,500 foot elevation in the 12-to-20-inch precipitation zone. The topography is rough, steep, and mountainous. The vegetation types (timber and sagebrush-grass) occur as distinct types interspersed with each other. The forest types occur as dense to open stands of conifer. In the higher areas above 9,000 feet, the dominant species are Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). In the mature dense stands, the understory vegetation is mostly mountain huckleberry (*Vaccinium scoparium*) and pine grass (*Calamagrostis rubescens*). Openings in these stands are few and usually small, occurring as moist bogs or springs. Vegetation on these sites is elk sedge (*Carex geyci*), rushes (*Juncus* spp.), bentgrasses (*Agrostis* spp.), and aspen (*Populus tremuloides*).

In the middle part of this zone, the dominant tree species becomes lodgepole pine (*Pinus contorta*). In open mature stands there is some understory of mountain huckleberry, Canadian buffaloberry (*Shepherdia canadensis*), snowberry (*Symphoricarpos albus*), and prostrate juniper (*Juniperus horizontalis*). In younger, denser stands of lodgepole, there is very little understory. There are frequent openings or parks occupied by big sagebrush, Idaho fescue (*Festuca idahoensis*), bentgrass, timothy grass (*Phleum alpinum*), yarrow, and a variety of flowering plants. Moist areas and park fringes are often lined with aspen.

The lower portion of this zone marks the lower limit of the conifer type. Limber pine (*Pinus flexilis*) and aspen are widely associated with the fir. The forest type is more open and trees more widely spaced. The common understory is big sagebrush, bitterbrush, snowberry, and pinegrass. Generally, this type occupies the more favorable north or east slopes.

The drier sites are occupied by sagebrush-grass types. Big sagebrush is usually dominant, with an understory of bluebunch wheatgrass, Idaho fescue, junegrass, balsamroot, paintbrush, lupine, and a wide variety of flowering forbs. Streams and valley bottoms usually support willow (*Salix* spp.), cottonwood, and aspen.

The vegetation in this zone is in better condition and more stable than in the other zones. Recovery from disturbance is fairly rapid.

The threatened or endangered plant species (U.S. Fish and Wildlife Service list) have not been inventoried in the Grass Creek area.

Wild Horses

Two wild horse areas are included in this study area. The largest numbers, now estimated at 300 to 350 head, are in the Fifteenmile and Tatman Mountain areas. A comprehensive inventory in the summer of 1974 tallied 23 separate bands. Subsequent spot checks indicate good colt crops and a very "healthy" rate of increase. It is estimated that these animals will double their population in less than ten years if no control measures are initiated. The present population consumes at least 3,600 animal unit months (AUMs) of forage annually and is competing with livestock and game for food, water, and space. In 1974 Hedrick reported that forage conditions were poor and overgrazing damage was clearly evident. (See district file report: 4700.1 Fifteenmile Management Area; H. Hedrick, Range Technician.) Hedrick also reported that these horses had little tolerance for people and would move out of areas where seismograph crews were working.

A second wild horse herd is located in the vicinity of the Little Sand Draw oil field, ten miles northwest of Gebo. About 30 horses inhabit this area. Current inventories indicate that this small herd of five bands is not growing at the same rate as the Tatman Mountain herd. In 1974, Hedrick reported that these horses were much tamer and could be approached more easily. They frequent the Little Sand Draw oil field and seem to be compatible with that operation.

Domestic Livestock

One hundred and eight ranching operations graze domestic livestock in approximately 160 allotments. Each allotment contains varying amounts of private, state, and public lands. The public lands total 940,000 acres producing 105,000 AUMs of forage. This use is made annually with approximately 39,000 sheep, 30,000 cattle, and 160 domestic horses. The actual use varies slightly each year, depending upon weather and forage conditions.

The lower elevations are used mostly in the fall, winter, and early spring by sheep and some cattle. Seasons of use vary between allotments, but the bulk of the use is made between May 1 and October 15 each year.

Most of the ranch baselands are located along the major river and creek drainages where irrigation water is available for hay and crop production. Most operations feed their livestock during the winter and early spring months

and then graze on native range the balance of the year. Since nearly 70 percent of the study area is public land, the importance and magnitude of grazing use is readily apparent.

The physical factors affecting grazing are vegetation, topography, weather, and water. Of these, water is the one factor having the most direct relationship between grazing and the production of oil and gas. These relationships will be discussed in the impact section of this report.

Fish and Wildlife

Introduction

The variations in soils, precipitation, elevation, and topography found over the study area provide for a diversity of wildlife habitats. A discussion of the fauna of this area must consider the suspected presence of endangered mammals, several big game species, several upland game species, waterfowl, game and non-game fish, raptors, predators and furbearers, small mammals, shore birds and other non-game birds, and reptiles and amphibians. Information available concerning some of these animal groups is fairly detailed and up-to-date. For other groups, information is of a general nature or unavailable. A list of species known or suspected to exist in the study area can be found in the appendix.

Threatened or Endangered Species

Over the last several years evidence has continued to mount that the northern Rocky Mountain wolf exists in the study area. Tracks, scat, and reported observations indicate that the wolf may at least seasonally or periodically frequent the western half of the study area. Considering known aspects of wolf ecology, it seems reasonable to expect that wolves would be found in and around big game concentration areas and in areas away from human activity centers. Wolf information is scant, but is of sufficient substance that we must recognize certain portions of the Gooseberry Creek, Grass Creek, Cottonwood Creek, and Owl Creek drainages as possible wolf habitat. Little more can be said concerning the wolf or its habitat in the study area.

Other federally listed endangered species which may occur in the study area include the black-footed ferret and the American peregrine falcon. Since there is a fairly large prairie dog population in the study area, it is quite possible that the black-footed ferret could be found. Occasionally in the past, the peregrine falcon has been observed along the Big Horn River. No nesting has been documented, so it appears that these observations have been of migrant birds. Several other fish and wildlife species have recently appeared on a state rare and endangered species list. This list is presently undergoing revision by the Wyoming Game and Fish Department. State-listed rare and endangered species will not be considered as such until such time as we receive a revised rare and endangered species list from the state.

Big Game

Elk Approximately 129,000 acres of the study area are considered elk habitat. This includes 9,000 acres of summer range and approximately 120,000 acres of winter range. This habitat supports an estimated base population of 846 animals. The winter range in the study area is crucial habitat for the herd which summers mostly on the Shoshone National Forest to the west. Elk winter mostly in the upper reaches of the Owl Creek, Cottonwood Creek, Grass Creek, and Enos Creek drainages. Here, between the elevations of 7,000 and 8,500 feet, they utilize the open south and east facing exposures and the open wind-swept grassy ridgetops. Major forage species include bluebunch wheatgrass, western wheatgrass, junegrass, mountain brome, Idaho fescue, and big sagebrush. Elk utilize the broken topography and the conifer and aspen timber types for cover and protection. There are an estimated 140,000 elk days of use made in the study area. The estimated annual harvest of about 282 elk comes from Wyoming Game and Fish Department hunt areas Nos. 63 and 64. Population, harvest, and habitat data are shown in Table 14.

Mule Deer An estimated base herd of about 6,125 mule deer utilize the study area. Probably half or more of these animals are year-long residents of the badlands and river bottom areas of the study area. The remainder of the herds winter in the study area and migrate to and from the higher elevations in the Shoshone National Forest in the spring and fall. The migrant herds winter primarily in the foothills below 7,500 feet. These ranges are characterized by scattered stands of juniper and limber pine, rocky topography, and sagebrush slopes and draws. The most important forage species is Wyoming big sagebrush. Black sagebrush and rabbitbrush are also important browse species.

According to the Wyoming Game and Fish Department, the migrant mule deer populations utilizing the higher elevation areas in the traditional winter ranges have declined significantly in the last 10 to 15 years. At the same time, smaller resident herds utilizing the lower elevation badlands, the Big Horn River bottom, the lower Greybull River, and the lower drainages of numerous smaller streams have remained stable or increased somewhat. The resident herds using the bottomlands utilize a wider variety of forage species. In addition to sagebrushes and rabbitbrush, Russian olive, chokecherry, rose, native plum, silverberry, alfalfa, and other agricultural crops provide deer forage. There appears to be increased use of the badland areas west of the Big Horn River during the winter months as compared to other times of the year. This may be related to the fact that snow is more often readily available during the winter months as a water source. Most of the area south of the Greybull River and north of Highway 120 and the Gooseberry Secondary is a hot, arid badland. A very sparse deer population is found over much of this area with a few concentrations identified. (See Map 7.)

Wyoming Game and Fish Department hunt areas 119, 120, 127, 125, and 126 are found in the study area. Also portions of areas 124 and 118 are included. In these hunt areas there is an estimated average annual harvest of 1,225 mule deer. The study area contains an estimated gross

habitat acreage of 1,200,000 for mule deer. Estimated acreage of known, crucial habitat or concentration areas is 160,000 acres. Approximately 55,500 deer months of use are made of this habitat. Table 14 contains other habitat information related to producing oil and gas fields.

In recent years, a controversy over mule deer management has arisen. Land owners have become increasingly intolerant of deer using private range and haylands. Some land owners have demanded that the Game and Fish Department reduce or totally remove herds in certain areas. Sportsmen groups feel that deer populations are too low and oppose any further herd reductions. Good detailed information concerning specific herd units, movements and concentration areas, habitat condition and trend, conflicts with other resource uses, and habitat carrying capacity is presently lacking.

White-tailed Deer Small, relatively little known populations of white-tailed deer are found in several locations in the study area. An estimated 32,000 acres of habitat known to be occupied by white-tailed deer have been identified. (See Map 7.) White-tailed deer habitat is generally associated with riverbottom and agricultural lands. Mule deer are usually found in the same areas.

Pronghorn Antelope The Wyoming Game and Fish Department considers nearly 1,000,000 acres of the study area as winter or year-long antelope habitat, excluding only the higher elevation areas on the west side. The base winter population is estimated at about 992 animals. While certain seasonal ranges of several herds are well known, seasonal movements, migration routes, critical habitats, and concentration areas have not been thoroughly documented for the study area.

In the past two winters, antelope have been observed wintering in Buffalo Basin, in the upper drainage of Fifteenmile Creek just east of Meeteetse, southeast of the Highway 120 crossing of Grass Creek, in the area between Blue Ridge and the junction of Highway 120 and the Gooseberry Secondary, and scattered over the general area west of the Big Horn River between Worland and Basin. (See Map 7.) Herds observed have numbered between 10 and 100 animals.

The northeast two-thirds of the study area is quite poorly watered. It is suspected that this may be a significant factor contributing to low fawn production and survival and thus to the sparse animal population found here. Available information indicates that Wyoming big sagebrush, black sagebrush, lanceleaf rabbitbrush, rubber rabbitbrush, Nuttall's saltbush, winterfat, and black

TABLE 14
Habitat, Harvest, and Populations for Selected Wildlife Species in Study Area

	Est. Avg. Annual Harvest	**Est. Populations or Densities**[1]	**Est. Gross Habitat Acreage**	**Est. Acreage of Known Crucial Habitat or Concentration Areas**	**Est. Acreage of Known Important Habitat in Producing Fields (KGS)**	**Est. Acreage of Habitat on Public Lands in Producing Fields**	**Est. Acreage of Habitat Under Fed. Mineral Ownership in Producing Fields**
Elk	282	846	129,000	120,000	4,880	2,760	4,040
Mule Deer	1,225	6,125	1,200,000	160,000	10,080	6,880	8,240
White-tailed Deer	Unknown	Unknown	32,000	Unknown	—	—	—
Antelope	248	992	1,000,000	Unknown	32,200	24,400	29,080
Sage Grouse	894		800,000	80,000	8,800	5,800	7,760
Chukar	3,059		Unknown	60,000	5,520	1,640	5,520
White-tailed Prairie Dogs			Unknown	16,000	2,920	2,600	2,600
Cottontail[2]	5,948						
Dove[2]	1,000						
Geese[2]	170						
Ducks[2]	2,974						
Pheasants[2]	887						
Hungarian Partridge[2]	243						

[1]Local Wyoming Game and Fish Department personnel provided estimates of the average annual harvest levels for elk, mule deer, and antelope expressed as percentages of the base winter populations. These percentages and an average annual harvest figure for each species based on 1973, 1974, and 1975 harvest reports were used to calculate the populations for these species in the study area.

[2]Populations, densities, gross habitat acreages, or crucial habitat acreages for these species have not been established. Available data is not specific or complete enough to make useful estimates.

greasewood are the primary browse species eaten by the pronghorns. Browse is the most important forage class, but certain grasses and forbs such as Sandberg's bluegrass and plains prickly pear may be important in the spring and early summer.

The estimated average annual harvest for the study area of 248 animals is taken in Wyoming Game and Fish Department hunt areas 77, 83, and part of 82. About 12,000 antelope months of use are made in the study area. Acreages of known antelope habitat found in producing oil and gas fields are shown in Table 14.

Bighorn Sheep and Moose Bighorn sheep and Shiras moose are present in the study area in small numbers. Higher elevations on the upper north fork of Owl Creek, Rock Creek, Mudstone Ridge, and Castle Rocks area are bighorn sheep range. Sheep and sheep signs have been observed there year around. Information is lacking on numbers, important habitat, and seasonal distribution.

Moose are occasionally observed along stream bottoms and in timbered areas in the upper Owl Creek, Cottonwood Creek, Grass Creek, and Gooseberry Creek drainages. Moose habitat is very limited and the population is apparently very small. There is not an open season on these moose.

Other Mammals

Predators and Furbearers The coyote, red fox, and bobcat range over most of the study area. Bobcats prefer the rocky ridges and drainages where cottontails are plentiful, while the red fox is more abundant at the lower elevations around agricultural lands along the Greybull and Big Horn Rivers and Owl Creek. Predation by these animals, especially coyotes, upon domestic livestock and the extremely high prices now being paid for their furs have placed heavy pressures upon them and many hundreds are taken annually. However, accurate data on populations, harvest, and density figures do not exist. All three of these animals are heavily dependent upon jackrabbits, cottontails, ground squirrels, and several other small rodent species for the major portion of their diet.

The mountain lion and black bear are considered trophy game animals in the State of Wyoming. However, under state law, if these animals cause damage to livestock, they are treated as predators. The most recent mountain lion reports came from the Upper Enos Creek and Grass Creek areas in 1975.

Black bear, more common than the mountain lion, prefer higher elevations in the aspen, conifer timber types. Black bear are hunted in the Upper Owl Creek, Grass Creek, Cottonwood Creek, Enos Creek, and Gooseberry Creek drainages. Usually, a few black bears are taken by hunters each year. A few are killed by sheep ranchers. Wyoming Game and Fish Department records indicate 50 to 100 hunter days expended each year on black bear.

The northern Rocky Mountain wolf and the black-footed ferret, both suspected inhabitants of the study area, have been discussed in the endangered species section.

Animals classified as furbearers by the state include beaver, badger, muskrat, mink, and marten. Beaver, muskrat, and mink are found in suitable riparian habitat along all the perennial stream drainages in the study area. Muskrat and mink can also be found around the lakes, ponds, and small reservoirs and river sloughs.

The badger is widespread and feeds primarily on burrowing rodents, such as ground squirrels, prairie dogs, and pocket gophers. The pine marten is found in and near the conifer forests. Its major prey species is the red squirrel.

Raccoons and striped skunks are fairly abundant along the stream-bottom areas and lowlands, especially around agricultural lands.

Accurate data on population, harvest, and density of predators and furbearers are not available.

Small Mammals The cottontail rabbit is classified as small game in Wyoming and hunting of them is becoming increasingly popular. Two species of cottontail inhabit the study area. The mountain cottontail is found in forested areas and the desert cottontail inhabits open desert and prairie. Nearly 6,000 cottontails were harvested in the study area in 1974. Broken topography, rocks, dry washes, along with sagebrush, yucca, and other shrubs provide the cottontail with important protection from predators and harsh winter conditions. Sagebrush, rabbitbrush, snakeweed, and saltbush provide the bulk of winter feed for the cottontail, while a wide variety of other species are used throughout the balance of the year. The cottontail rabbit is extremely important as a food source, especially in the winter, for most of the larger predatory animals and birds in the study area.

White-tailed jackrabbits occur in limited numbers throughout most of the study area where the sagebrush, greasewood or saltbush vegetation types occur. Their populations are cyclic and they are a food source for predators, especially coyotes.

At least 20 white-tailed prairie dog towns or complexes have been identified (Map 7). It is estimated that the towns identified occupy approximately 16,000 acres. (See Table 14.) Some colonies are large and, as mentioned previously, provide potential black-footed ferret habitat. While prairie dogs eat a wide variety of plants in the vicinity of their burrows, the bulk of their diet is Nuttall's saltbush and grasses such as blue grama and western wheatgrass. In addition to providing a food source for predators and raptors, prairie dogs dig burrows which provide cover and nesting habitat for various other wildlife species such as burrowing owls, snakes, rabbits, and weasels.

In areas of rougher topography, rocky ledges, and deeply cut washes, the bushy-tailed wood rat, deer mouse, and least chipmunk are common. Porcupines are most common in the lodgepole pine forests and are also found in the limber pine-juniper areas and along the riverbottom riparian habitat. The deer mouse and least chipmunk are most abundant in the sagebrush type. Other small mammals of the sagebrush grasslands include Ord's Kangaroo rat, sagebrush vole, Richardson ground squirrel, and the northern pocket gopher. The yellow-bellied marmot is common around higher elevation meadows where rocky

outcrops provide good denning areas and escape cover. Within the vicinity of the conifer forest areas, the red squirrel, the red-backed vole, and the golden-mantled ground squirrel are common. The northern flying squirrel may also be present here.

A variety of other small rodents, bats, and shrews are either known to occur or suspected to occur in the study area. (See species list, Appendix 3.)

Upland Game Birds

Sage Grouse While sage grouse population and habitats have been well monitored in some portions of the study area for many years, other areas have had little or no work done in them. Approximately 800,000 acres of the study area have been considered as gross sage grouse habitat. It is recognized, however, that within this acreage, the actual sage grouse habitat area is made up of many smaller sites which provide habitat requirements. From available information, we have estimated approximately 80,000 acres of known critical habitat or concentration areas. Eighteen strutting grounds have been documented and observed to some extent in the field. Five more suspected strutting grounds have been located but not confirmed to date. (See Map 7.)

Sagebrush, of course, is of utmost importance to sage grouse as food and cover, especially during the winter and nesting periods. During the spring and summer months, good quality, dependable water, and succulent forage such as found in wet meadows are of exceptional importance to hens with young broods.

Wyoming Game and Fish Department feels that the sage grouse population is somewhat under exploited at this time. The harvest in 1974 was estimated at 894 birds. Considering the information available, it is felt that a reasonably accurate population or population density estimate cannot be made at this time.

Table 14 shows estimated acreages of important sage grouse habitat found in producing oil and gas fields.

Chukar Partridge Chukars were first introduced into the study area in about 1940. Chukar populations are quite erratic from year-to-year due to a very high reproductive capacity and a very short life span. Annual chukar production is highly dependent upon weather conditions during the nesting and early brooding seasons. Chukars may be found scattered through many parts of the area, but concentration areas totaling 60,000 acres are found in the rough, rocky terrain of the lower Gooseberry Creek, Grass Creek, Prospect Creek, and Cottonwood Creek drainages. (See Map 7.)

Under normal conditions food availability is not usually limiting to chukar populations due to the variety of food they will consume and their small needs. However, in years when severe winter conditions with prolonged heavy snow cover and periods of extreme low temperature prevail, food availability on exposed feeding sites can become extremely critical. Factors which normally appear limiting are the rough, rocky terrain which is preferred escape cover and reliable water. Dependable water is probably the most important limiting factor affecting chukar populations in the study area. The leaves and stems of cheatgrass brome and Sandberg's bluegrass and the seeds of cheatgrass brome are probably the most important food items for the chukar partridge in this area. Ants, grasshoppers, and the seeds of a variety of other weeds and grasses can also be important at certain times.

In 1974, the estimated chukar harvest was 3,059 birds for the study area. No population estimate is available. Table 14 shows important chukar habitat in producing oil and gas fields.

Hungarian Partridge and Ringneck Pheasant Huns and pheasants are found primarily near the agricultural and riparian lands. Much of the habitat for these species is on private land and is found on the lower portions of drainages such as Owl, Cottonwood, and Gooseberry Creeks and along the bottomland of the Greybull and Big Horn Rivers. Populations of these species are considered low. In 1974, harvest estimates were 887 pheasants and 243 Huns.

Blue Grouse and Ruffed Grouse Blue grouse and ruffed grouse are found in the extreme western portion of the study area at higher elevations primarily in the aspen and spruce fir timber types. Little other information is available concerning these species. Few birds are harvested and a population estimate is not available.

Mourning Doves During the period from early spring to fall, the migratory mourning dove is found throughout most of the study area, with the exception of heavy timber sites and the arid portions. Doves nest most successfully in trees, although they also nest on the ground in clumps of brush in otherwise open areas. Nesting cover is enhanced by open perches in the area. Highest densities occur in areas with interspersed trees and open land such as along the wooded streambottoms and in the area of scattered juniper and limber pine. Several studies indicate that doves are seed eaters, taking about 70 percent weed and forb seeds and 30 percent grass seeds and grain, when available. Good habitat depends upon water being available within the daily cruising radius.

Doves have only recently been classified as game birds in Wyoming and have not yet become very popular with hunters. Little management information has been collected on this species. In 1974, an estimated 1,000 doves were harvested in the study area.

Waterfowl

Within the study area, the Big Horn and Greybull Rivers, lower portions of Owl, Cottonwood, and Gooseberry Creeks and the many small stock ponds and reservoirs provide habitat for ducks and geese. The Big Horn River along the east side of the study area provides the most important waterfowl habitat. The river provides important nesting habitat for Canada geese and for a variety of species of ducks. During the fall and early winter many thousands of ducks migrate through the Big Horn Basin, utilizing the Big Horn River and nearby agricultural lands for feeding and resting. Ponds and other stream drainages are also used in the fall until freezeup. Some drainages

which would otherwise be frozen are kept open by warm production water coming from producing oil and gas fields. Notable among these are Cottonwood Creek and Sand Draw drainages below the Hamilton Dome field. It is estimated that there are approximately 50 miles of formerly ephemeral drainage carrying permanent flows of discharge water. (See water section for fields producing discharge water.) It is not known what percentage of this type of drainage provides waterfowl habitat. Neither has it been determined specifically how production water quality influences waterfowl use of these waters. Canada goose and duck breeding ground surveys, conducted by the Wyoming Game and Fish Department, indicate that Canada geese, mallard, teal, redheads, gadwall, pintail, coot, and mergansers are the most plentiful, breeding waterfowl. (See Table 15.)

In 1974, an estimated 170 geese and 2,974 ducks were harvested in the study area.

TABLE 15
Duck and Goose Breeding Ground Surveys
1973 and 1974
Wyoming Game and Fish Department

OTTO SURVEY AREA, BIG HORN COUNTY
152 Sq. Miles

Species	1973	1974	Avg.
Mallard	46	30	38
Teal	25	37	26
Shoveller	2	2	2
Coot	120	30	75
Gadwall	10	10	10
Pintail	10	18	14
Scaup	2	8	5
Redhead	35	—	18
Widgeon	2	4	3
Ruddy	2	—	1
Unknown	38	24	31
Totals	292	163	228

WORLAND SURVEY AREA, WASHAKIE COUNTY
15 Sq. Miles

Species	1973	1974	Avg.
Mallard	62	26	44
Gadwall	2	—	1
Teal	10	2	6
Merganser	10	2	6
Coot	2	2	2
Pintail	4	4	4
Widgeon	—	2	1
Unknown	9	2	6
Totals	99	40	70

Geese—Big Horn River Drainage, April 1973 & 1974
Wedding of the Waters to Greybull

Females on Nest		Single Males		Pairs		Groups	
1973	1974	1973	1974	1973	1974	1973	1974
—	8	11	22	15	17	39	23

Raptors and Other Birds

Roughly the eastern three-quarters of the study area is a winter concentration area for golden eagles and rough-legged hawks. These raptors depend upon the cottontail rabbit as their major winter food source. Bald eagles are often observed wintering along the Big Horn River. Some may winter along the Greybull River. Along with the eagles, the marsh hawks, redtail hawks, American kestrel, western burrowing owls, great-horned owls, Swainson's hawks, ferruginous hawks, short-eared owls, prairie falcons, goshawks, Cooper's hawks, and sharp-shinned hawks have been observed in the spring and/or summer. Bald and golden eagles, redtail hawks, kestrels, marsh hawks, and great-horned owls are all known to nest in the area. The turkey vulture is a common summer resident.

Cliff areas, rock outcrops, and at some times shrubs provide nesting sites for the majority of the birds of prey. In open country, utility poles, fence posts, isolated trees, rock outcrops, and other isolated structures provide important perches for hunting raptors. These are often well used along transportation routes where traffic-killed small animals make an attractive ready-made food source. Raptors are often run down by automobiles while attempting to feed on road-killed rabbits. Raptor electrocution may still be a problem on some of the older powerlines.

Many stock ponds, reservoirs, streams, and the rivers provide acreages of shoreline and riverbank nesting and feeding habitat necessary for continued existence of shore birds. Great blue herons, gulls, grebes, snipe, lesser yellowlegs, willets, avocets, terns, upland sandpipers, killdeer, and northern long-billed curlews probably all nest in the study area. These species migrate through the area in spring and fall. The various vegetation types provide habitat for a surprising variety of songbirds. Most are migratory, leaving during the winter.

Seed-eating birds, such as the horned lark, vesper sparrow, lark bunting, and savannah sparrow, are common, as are largely insectivorous birds such as the western meadowlark, loggerhead shrike, and mountain bluebird. Bank swallows, cliff swallows, and common nighthawks are commonly observed aerial insectivores. Flickers, common grackles, western kingbirds, various warblers, goldfinches, and robins are usually found in the riparian vegetation.

Other birds commonly found near agricultural lands and along the rivers are crows, Brewer's blackbird, yellow-headed blackbird, red-winged blackbird, and black-billed magpies. Sage thrashers and Brewer's sparrows prefer the sagebrush type. The raven, hermit thrush, ruby-crowned kinglet, Canada jay, Clark's nutcracker, stellar jay, downy woodpecker, red-breasted nuthatch, and grey-headed junco are the birds most commonly heard or observed in the higher elevation forests and riparian habitats. There is presently little information concerning the densities, distribution, and limiting factors of these species in the study area.

Reptiles and Amphibians

Information is extremely limited concerning reptiles and amphibians in the study area. The blotched tiger salamander, leopard frog, boreal chorus frog, plains spadefoot toad, and the great plains toad can be found around streams, small temporary ponds, and reservoirs.

Reptiles known in the study area include the sagebrush lizard, eastern short-horned lizard, prairie rattlesnake, bullsnake, and wandering garter snake. The eastern yellow-bellied racer and red-sided garter snake probably occur near the rivers. Snapping turtles and western soft-shelled turtles have been collected along the Big Horn River.

Invertebrates

Only cursory information is available concerning invertebrate life in the study area. A few species of insects such as the western harvester ant are obvious due to their activities in the saltbush, greasewood, and sagebrush grassland vegetation areas. Denuded rings ten to twenty feet across surround anthills numbering one to several per acre. A ring of larger, more vigorous sagebrush plants several feet wide surrounds the denuded area. This pattern around anthills gives the appearance of sagebrush rings which are evident over vast acreages of the study area.

Grasshoppers are plentiful during the summer and fall months, and sometimes reach epidemic proportions over large areas.

Ants and grasshoppers and a variety of other insects are important because of their impacts on ecosystems, especially in food chains and as primary consumers of vegetation. Insects rank as one of the three major groups of herbivores. Many animals, such as shrews, nighthawks, eastern short-horned lizards, bats, skunks, and burrowing owls, depend upon insects for all or part of their diets.

Aquatic insects such as mayflies, stoneflies, caddisflies, aquatic two-winged flies, and beetles are important food sources for various fishes, amphibians, and other members of aquatic food chains.

Fisheries

Wardell Reservoir, in the northern part of the study area, is the only known reservoir fishery supporting game fish (Map 8). This reservoir has proven to be marginal habitat for game species. Numerous plants of walleye and catfish have been made here, but success of the plants has not been good and the fishery must be considered poor. Nearly 50 miles of stream habitat known to support fish are found on public lands. (See Tables 16 and 16a.) An additional 32.5 miles of fish-supporting stream flow across private lands where the federal government owns minerals.

The total stream fisheries resource in the study area is generally limited in extent and quality. The better trout fisheries involving public lands are found on the Big Horn River, the Greybull River and the south fork of Owl Creek. A total stream fisheries survey has not been made in the study area. There are numerous small streams about which no information has been collected either by the BLM or the Wyoming Game and Fish Department. About 20 of these small streams have significant amounts of public land along them. A stream fisheries habitat survey will be made in the near future to determine the status and habitat of fish in these areas.

Game fish of the study area include rainbow, brown, brook and cutthroat trout; walleyes; sauger; ling; channel catfish; and mountain whitefish. Some of the nongame fish which have been identified are black bullheads, stonecats, white suckers, river carpsuckers, long-nose dace, long-nose suckers, mountain suckers, flathead chubs, silvery minnow, plains killifish, and carp.

Ecological Interrelationships

Most of the Grass Creek study area consists of four biomes—three are terrestrial and one is aquatic. Specifically, these biomes are the cold desert, the sagebrush-grass, the conifer forest, and the aquatic. Each of these communities encompasses a large number of very complex interrelationships between the living and non-living elements. The more important elements within the study area should be evident after reading the previous sections on soils, vegetation, climate, and animal life.

The aquatic communities are found in and adjacent to the rivers, perennial streams, reservoirs, ponds, and springs of the area. The habitat for these communities includes both the water area and the riparian areas immediately adjacent.

Those portions of the Big Horn and Greybull Rivers within the study area are mostly in the middle stages of geologic succession. There are no waterfalls, and rapids have diminished to ripple areas. Sandbottom pools are more common than mudbottom pools, very probably due to the flushing and cleaning effect of annual spring runoff and high water. The fish species present and the apparent status of invertebrate populations are also indicative of the middle stages of succession.

Riparian areas adjacent to these rivers are mostly stabilized and support various types of vegetation such as willows, cottonwoods, and cattails. Wide flood plains and old stream channel meanders are also evidence of midstage succession. Man-caused changes in flow and water quality with dams, irrigation diversions, return flow drains, and overall pollution, have altered the natural stream processes, but to what degree has not been determined.

Lesser perennial streams such as Wood River, Owl Creek, Cottonwood Creek, Grass Creek, and Gooseberry Creek and their live tributaries are mostly in earlier stages of succession than the rivers discussed above. Gradients are greater with more defined waterfalls, rapids and ripple areas. Except in the very lowest reaches, these streams show little sign of meandering. Channels are narrow and deep and banks are less stable. Permanent riparian vegetation is lacking or consists of occasional cottonwood groves and sagebrush or greasewood stands. This general lack of stable riparian vegetation is due to extreme fluctuation, unseasonal water levels, destructive force of heavy spring runoffs, occasional cloudburst activity, and intensive use by livestock and wildlife. Of these factors, livestock use has the most pronounced effect. At the lower elevations and lower reaches of these streams succession is more advanced, but in many cases irrigation has altered the natural processes.

TABLE 16
Known Fish Supporting Stream Habitation
Grass Creek Oil and Gas EAR Area

Stream	Stream Miles on Public Land	Est. Miles of Fed. Mineral—Private Surface Ownership	Fish Species Identified[1]
Wood River[1]	0.35[2]	0.0	Cutthroat trout & various non-game fish
Greybull River[1]	6.15	3.0	Brown, rainbow & cutthroat trout, Rocky Mtn. whitefish & various non-game fish
Big Horn River[1]	12.85	0.5	Brown, rainbow trout, sauger, channel catfish, walleye, various non-game fish
S. Fork Owl Creek[2]	20.80	3.0	Rainbow & brook trout, various non-game fish
N. Fork Owl Creek	1.35	2.5	Brook trout & various non-game fish
S. Fork of the N. Fork of Owl Creek	2.25	2.5	Rainbow & brook trout & various non-game fish
Cottonwood Creek	8.25	11.0	Rainbow & brook trout & various non-game fish
S. Fork Cottonwood Creek	0.45	0.5	Rainbow & brook trout & various non-game fish
Grass Creek	2.10	6.5	Rainbow & brook trout & various non-game fish
Gooseberry Creek	12.35	3.0	Brook trout & various non-game fish
Enos Creek	1.20	0.0	Brook trout & various non-game fish
TOTAL	68.10	32.5	

[1]Personal communication with Louis Pechacek, Wyoming Game and Fish Biologist, Cody, Wyoming.
[2]BLM stream survey, 1976-77.

TABLE 16a
Fish Species Known to Occur in Grass Creek Planning Unit
(Wyoming Game and Fish Department Records)

Stream Segment	Trout Species	Other Species[1]
South Fork Owl Creek to Anchor Res.	Rainbow, Brook, Yellowstone Cutthroat	None listed
Rock Creek	Rainbow & Yellowstone Cutthroat	None listed
North Fork Owl Creek	No fishery apparent	Unknown
Middle Fork Owl Creek	No fishery apparent	Unknown
Cottonwood Creek—downstream to Hamilton Dome	Rainbow	Mt. Sucker, Long-nose Dace
Grass Creek—downstream to Grass Creek	Rainbow & Brook	None listed
Enos Creek	Brook	None listed
Gooseberry Creek—that portion in Park County	Brook	
South Fork Owl Creek from Anchor Res. downstream to North Fork Owl Creek	Rainbow, Brook, Yellowstone Cutthroat	
Little Buffalo	No fishery apparent	
Buffalo Creek	No fishery apparent	
Gooseberry Creek—that portion in Hot Springs County	Brook	None listed
Middle Creek	No fishery	
Left Hand Creek		
Grass Creek—from Grass Creek to confluence with Cottonwood Creek	Rainbow, Brook	None listed
Prospect Creek	No fishery apparent	
Cottonwood Creek	None listed	Mt. Sucker, Long-nose Dace

TABLE 16a (continued)

Stream Segment	Trout Species	Other Species[1]
Greybull River—that portion in Park County	Brown, Cutthroat, Whitefish	
Red Canyon Creek	No fishery apparent	
Owl Creek	Brown	Unknown
Coal Draw	No fishery	Killifish
Sand Draw	No fishery	
Cottonwood Creek—from confluence of Grass Creek to Big Horn River	No fishery	
Little Gooseberry Creek	No fishery	
Gooseberry Creek—that portion in Washakie County	No fishery apparent	
Fifteenmile Creek	No fishery	No fishery
Tenmile Creek	No fishery	No fishery
Fivemile Creek	No fishery	No fishery
Elk Creek	No fishery	
Greybull River—that portion in Big Horn County	Brown, Cutthroat	Whitesucker, Long-nose Sucker, Mt. Sucker, Carp, Flathead Chub, Long-nose Dace
Big Horn River	Rainbow, Brown	Walleye, Sauger, Channel Catfish, Stonecat, River Carpsucker, Ling, Northern Red Horse, Whitesucker, Mt. Sucker, Long-nosed Sucker, Carp, Flathead Chub, Sturgeon Chub, Sand Shiner, Flat-head Minnow, Silvery Minnow, Plains Minnow, Long-nose Dace

[1]Wyoming Game and Fish Department does not have data on fish other than trout in this area. Where non-game fish have been identified in this table, information is from stream surveys done by Worland District BLM employees in the summer of 1977.

Food relationships in the aquatic communities are complex. Some are strictly aquatic such as filamentous algae-caddisfly larva-flathead chub; larva-trout-predator (e.g., eagle, kingfisher, or man). In the riparian zone some food chains are terrestrial, such as: cattail-muskrat-mink; aspen-beaver. Other chains are both aquatic and terrestrial, such as: algae-snail-mallard-fox.

Community relationships within the aquatic-riparian areas are most obviously exemplified by the food-chain interdependence of one species upon another. A wide variety of other species interactions occurs, some quite simple and obvious, others very complex and inconspicuous but nonetheless important. To attempt to describe them all here is not possible or productive. It is important to understand, however, that because of the variety and the complexities, the riparian communities are probably more important to the total area than any of the other communities.

Habitat modification by plants and animals in a desert biome such as this is normally so slow as to be barely discernible under natural conditions. However, conditions are not natural in the desert biome of the Grass Creek study area. With the exception of a few small sites, virtually all plant associations are in a "disclimax status," due to past and present grazing of livestock. Range studies by Fisser (University of Wyoming, 1964 to present) on this area and similar adjacent areas indicate that conditions are poor to fair and trends static to downward in most of the plant associations. The native animals found here are discussed in the wildlife section. It appears that the long-term effect of livestock grazing with respect to other animals in the community has been to decrease populations more than to change species.

Physiographic changes can modify the environment quite apart from the changes brought about by organisms. Flood plains become better drained as stream courses cut more deeply. Silting in low places raises the level of mineral soils. Chemical changes in the soil result from leaching or accumulation of salts. Such modifications of habitat produce vegetation changes called "physiographic succession." Those plant associations and variations of them such as big sagebrush-bluebunch wheatgrass, Nuttall's saltbush, greasewood, greasewood-saltbush and bud sage exhibit this type of succession in the study area.

Major producers in the community are cheatgrass brome, blue grama, Nuttall's saltbush and big sagebrush. Greasewood, halogeton, rabbitbrush, western and bluebunch wheatgrasses, and needle-and-thread grass are major producers on some sites. Most of the food manufactured by plant producers is taken at the primary consumer level by domestic sheep and cattle.

Insects—primarily grasshoppers and ants—undoubtedly consume significant quantities of plant material. Wildlife species such as antelope, elk, deer, rabbits, kangaroo rats, mice, and prairie dogs make up the third important primary consumer group. Man is the most important secondary consumer in this ecosystem. He harvests the livestock as well as some antelope, elk, deer, rabbits, and sage grouse for food. Coyotes, eagles, foxes, badgers, and other wild predators are also secondary consumers. These predators take mostly rabbits, rodents, sage grouse, and occasional fawns. Coyotes take some sheep. Species such as coyotes, eagles, and great-horned owls sometimes assume the role of tertiary consumers when they take smaller carnivores and insectivores. In some instances one species may be extremely dependent upon another. Such is the case with sage grouse upon sagebrush.

The cold desert biome is naturally arid and subject to periods of extreme drought. Wet and dry years cause wide fluctuations in the amount of plant material produced. This fluctuation, coupled with excessive livestock use not necessarily based on changes in forage availability, is largely responsible for the depleted production potential. Relatively little dead organic matter accumulates in this environment; correspondingly, the activities of "transformer" organisms are limited.

Man's efforts to increase livestock production have included surface-water development. This has resulted in severe overuse of vegetation near these water developments by livestock and wildlife. Such development has enabled consuming elements to make increased use of the energy "fixed" by the producing elements.

Most of the obvious cases of interdependency of one species on another are food related. The wintering golden eagle population is almost totally dependent upon cottontail rabbits for food during winter months when prairie dogs and other rodents spend little time above ground. Some prairie dog colonies appear to be almost totally dependent upon Nuttall's saltbush for food. In such situations there is little other vegetation over large areas. Some situations of species interdependence are related to nesting sites and cover. Burrowing owls depend upon burrowing rodents—usually prairie dogs—for their burrows. Brewer's sparrows are dependent primarily upon sagebrush for nest sites.

Nearly all the wild horses found in the study area are located in this community because of its vast unfenced, uninhabited nature.

A wide variety of species interactions involve lesser organisms throughout the cold desert biome, but it is not possible or productive to attempt to describe them all here.

The sagebrush-grass community, a part of the cold desert biome, has been subjected to the same intensive livestock grazing use as the cold-desert biome discussed above. This area is also in a disclimax or subclimax state of succession. However, vegetation condition ranges from poor to excellent and trends vary from downward to improving. This wider diversity in condition and trend is due to the diversity in topography, complexity of slopes and aspects, and generally higher precipitation. Most of the native animal species are the same as found in the cold desert; populations are generally higher per unit of area.

Sagebrush and the major grass species are the main producers in this community. Domestic livestock are the primary consumers, although deer and elk compete more here. Some wildlife use is seasonal. For example, deer and antelope use the area in the spring, summer and fall and then migrate to lower areas for winter. On the other hand, elk will use this area only in late winter-early spring.

Community relationships and species interdependencies are well defined and fairly stable with respect to the native flora and fauna; however, these are heavily influenced by livestock use. A good example of this interaction is the wet meadow-sage grouse relationship. These sites and their

succulent forb growths are very important to spring-summer grouse populations. Heavy livestock use of these choice sites creates competition for food, but equally important is that the protective cover is reduced, making the grouse (especially the young) more vulnerable to predators.

The conifer forest community is the smallest within the desert biome but is the most advanced in terms of ecological succession. Most stands are mature or overmature. In many cases, juniper and limber pine appear to be spreading into the surrounding sagebrush grass sites. Vegetation condition is better here and recovery from disturbance is fairly rapid. The most important aspects of the forest community are its mixture of cover and food types and the watershed values.

The forest types vary from scattered, open limber pine and juniper on the south slopes to heavy, closed canopy stands of lodgepole pine, Douglas-fir, and spruce on the north and east slopes. Numerous openings and breaks create edge effects important to the many species living here. Grasses and shrubs are the major food producers and the food chains are the same as or similar to those in the other terrestrial biomes. In addition, there are some chains unique only to the forest type such as pine cone-pine squirrel and chipmunk-predators, insects-woodpeckers and flickers-predators.

Landscape Character

The massive scale of lands in the area and scarcity of inhabitants gives the area a remoteness seldom encountered in other sections of the country. The lands are mostly arid desert lands with little variation in texture. Most interest in the landscape derives from clay bed coloring, geologic features, and background panoramas of the mountain ranges which rim the Big Horn Basin. Frequent wildlife encounters enhance the natural appearance of the involved lands.

The landscape involved in this study can be divided into five basic categories based primarily on physiographic features. The categories are: lower montane, foothills-basins, badlands, benches, and bottoms. Within each of these categories several features or degrees of importance can be attached. Map 9 illustrates each region described below.

Lower Montane

The lower montane division can be delineated from the others by its overall wooded appearance, differences in relief and bedrock, diverse plant and animal communities, and greater precipitation. These lands are at the base of the Absaroka and Owl Creek Mountains which lie mainly within Shoshone National Forest and Wind River Indian Reservation. They seem more attractive for sightseeing and recreation to the general public than do most of the other lands within the study area. Limber pine, Utah juniper and Douglas-fir (in the upper reaches) add color and texture to the area. Spring floral displays are abundant; grasses and shrubs are lusher than the lands to the east.

The lands are dissected by several perennial streams including the upper parts of Cottonwood Creek, Gooseberry Creek, Grass Creek, Enos Creek, and Owl Creek drainages. At this point many of the streams are near their source and overall aesthetic quality is high.

Most soils derive from volcanic parent material. Colors vary from grey and green buffs to red or vari-colored shales with large amounts of lichen enhancing the coloration. Eroded sills, dikes, and plugs are common, such as are found in the Holy City area, on Sugarloaf Mountain, near upper Gooseberry Creek, and on Leon Baird Peak. Middle and background views of the Absaroka wilderness provide contrast, relief, and interest to these lower montane areas.

Foothills-basins

Moving east, the next major landscape type is a combination of rolling foothills and structural basins which parallel the crescent of the montane region described above. These lands vary in elevation from 4,600 to 6,200 feet. The lands are a series of anticlinal features which were formed on the flanks of the major upthrusts and are comprised mainly of sandstone rimrocks, alluvial stream terraces and tilted sandstone hogbacks. Since these lands are higher than the badlands to the east, precipitation is slightly higher, and snow melt dates are later. Utah juniper characterizes much of the category, interspersed with fairly dense stands of grasses and sagebrush. The major foreground color is derived from the juniper, but occasionally the sandstone bedrock has leached to form desert varnish against eroded cliffs. The oil and gas activity in the basin has centered on these lands since the early 1900s. Therefore, occasional oil field facilities are found in this area, including Grass Creek, Hamilton Dome, and Little Buffalo Basin fields. The region incorporates excellent opportunities for background views of the entire Big Horn Basin and the Big Horn, Bridger, Owl Creek, and Absaroka Mountains.

Badlands

A third major landscape present in the leasing area is the badlands which form the heart of the Big Horn Basin. The land is highly varied in color, texture, and relief, but relatively monotonous in terms of life forms present. The Willwood formation of rock forms the foundation for this area. Its brightly banded grey and red clays have been severely eroded by rain and wind to form hundreds of square miles of pillars, gullies, hoodoos, rounded knobs, and badlands topography. The lands, due to their rough nature, are nearly impassible even by four-wheel drive vehicles. This region is in the rain shadow of the Yellowstone Plateau and the Absaroka Mountains. Precipitation averages less than six inches a year. The vegetation has been heavily grazed and the overall appearance lacks interest and variety. Occasional intermittent washes and stock reservoirs dot the badlands, and scattered cottonwoods are present along some drainages.

The animal life in this area is scattered, but some species attract special attention. Notable among these are wild horses and eagles which are concentrated in the East Ridge-Tatman Mountain area. A herd of approximately 200 horses is present and almost free of the interference of human activity. The eagles feed largely on cottontail rabbits which are present at moderately high levels. This area is the most primordial group of lands in the district; the feeling of solitude, vastness and harsh conditions pervades this landscape.

Benches

The study area also includes a few bench or mesa-type features as well. Most notable of these is Blue Mesa southwest of Worland. These lands are slightly higher than the Willwood badlands and are evidently erosion-resistant portions of the Lance and Fort Union Formations. The foregrounds are relatively unvaried combinations of brown, sandy loams overlain by large areas of thick, canopied sage. There is a feeling of remoteness in the area, but it acquires most of its value when viewed in context with the surrounding lands. Due to its high relief, the mesas offer an excellent platform for viewing the entire Big Horn Basin with unrestricted views. The landscape present lacks color but is enhanced due to the scale of viewing possible.

Bottoms

The last major delineation of landscapes in the lease study area is the river bottoms which dissect all the other major land forms. These corridors vary from confined mountain cuts to rather broad alluvial terraces. As a rule, they vary from one-quarter to two miles wide with the main channel being only a few feet below the level of the surrounding bench. Agriculture has altered nearly all of this category with scattered ranch or farm headquarters and hay fields dotting the view. Most of the major travel routes parallel these channels in the Basin. Colors are harmonious pastels, but are muted; textures vary only from irrigated fields to the contrasting rangelands nearby. Relief is mainly a background or middleground aspect of the surrounding land form. Due to the presence of water, buildings, and domestic and wild animals, these lands have a moderately high value for general sightseeing.

Superimposed on the above landscape types are the values and presence of people in the Big Horn Basin. Some of the areas which are relatively harmonious landscapes receive little attention by the resident population or visitors. Conversely, some incongruous landscape elements in the area have high value to the region's population.

Map 9 highlights major population centers, travel corridors, and occupation zones in the use area. Lands within a line of sight (up to three-mile radius) of these use areas are subject to continual scrutiny from the general public. Actions which introduce disharmonious elements into the landscape here will usually receive negative reactions from the recreation public. The places where oil field activities already occur have affected some of the use areas. In addition, utilities and transportation systems parallel most of the travel corridors. In these cases, the landscape is already negatively altered and small scale visual intrusions do not individually affect the landscape. Systematic or repeated alterations do, however, have a significant effect.

As a rule, the resident population of the Big Horn Basin does not react negatively to industrial or agricultural use of the land. This is due perhaps to the dispersed nature of present uses and to the income these uses provide for Basin communities. Thus, population centers do not affect landscape evaluation in the study area. Out-of-state visitors in increasing numbers utilize the travel corridors and public lands as recreation areas. Out-of-state visitations on highways intersecting the Big Horn Basin are as follows.

TABLE 17
Annual Out-of-State Visitations

	Per Year
Highway 789 (at Basin)	505,470
U.S. 16 (Ten Sleep)	497,040
Hyattville Road (Manderson)	20,224
U.S. 16 (W of Cody)	888,992
Wyoming 30 (W of Basin)	14,340
State 171 (E Grass Creek)	9,340
Wyoming 431 (E of Hwy. 120)	11,680
Wyoming 433 (N Worland)	35,040
State 174 (W of Hamilton Dome Junction)	14,020

The BLM Unit Resource Analysis for this area listed a figure of 34,000 visitor days per year attributable to recreationists on Highway 120 in 1973; present figures are about 37,100. For the above groups, alterations in the landscape are more noticeable since their purpose in travelling is to view the areas they traverse. Especially on Highways 789 and 120, viewers will be sensitive to degradations of landscape character; these are two major travel routes to the east entrance of Yellowstone National Park.

For some county roads, the primary use is access to oil fields or mining areas. The Hamilton Dome, Grass Creek Basin, and Sand Draw roads were constructed by and are primarily used as oil company production routes. Lesser travelled roads which receive heavy recreational traffic include Fifteenmile Road, Greybull River Road (west of Meeteetse), and lower Cottonwood Creek Road.

Outdoor Recreation Values

The most detailed description of recreation values for the study area is included in the district BLM Unit Resource Analysis narratives and overlays for the former Cottonwood Creek, Grass Creek, and upper Greybull River planning areas. The Tatman Unit has not yet been included in the recreation information system.

The subject lands support a wide variety of recreational activities including hunting, fishing, off-road vehicle driving, camping, general and geologic sightseeing, and viewing wildlife. Since the Big Horn Basin encompasses an area

in excess of six million acres and a population of 30,000 or less, this use is not usually very intensive. Even though out-of-state visitors travel across these lands, they do not normally use them for recreation. The main exception is hunting and the varied forms of sightseeing. In 1974-75, over 1,200 visitor days were recorded in a two-week period each year during the big game season within the confines of the study area. This figure was based primarily on field counts taken in the upper Grass, Enos, Gooseberry, Cottonwood, and Owl Creek drainages and did not reflect use in the lower regions of the subject lands. Fishing is a major use of Sunshine Reservoir and the Big Horn River but also occurs at low levels elsewhere in this area.

Off-road vehicle use is scattered and sporadic, occurring usually in conjunction with hunting or sightseeing; visitor days are probably not over 10,000 to 15,000 per year for the entire southwestern Big Horn Basin. The area has a tremendous potential for viewing wildlife; but, to date, most use centers on hunting. Golden eagles are abundant in the hogbacks along Highway 120 and in the Tatman Mountain area. Marsh hawks, various owls, and other raptors winter along the Greybull River bottomlands and, to a lesser extent, along Gooseberry and Cottonwood Creeks. Rabbit, sage grouse, and chukar hunting is scattered throughout the area with sage grouse mainly at moderate elevations (Blue Mesa, Middle Fork, Owl Creek), chukar along the lower drainage areas, and cottontail rabbits abundant in several areas but especially high along lower Fifteenmile Creek.

Cultural Resources

Cultural resources (paleontological, prehistorical, and historical) are considered by the BLM to be integral and non-renewable portions of the human environment. They are often very fragile or limited physical remains of early life forms or of human activity. Even when there is no physical evidence of these activities, places where significant human events occurred and the natural environmental setting of the areas are considered cultural resources.

Paleontological Resources

The subject lands of this report are extensive in physical area and contain many geological formations which display paleontological values. Within these lands many types of preserved early life forms can be found. The area "is actually and potentially one of the most significant vertebrate fossil areas in North America" (Lillegraven and McGrew, 1976).

The collection of fossil remains began as early as 1880 by J. L. Wortman. Since then, many museums and universities have made field collections of paleontological specimens. The following institutions are among those who have done scientific studies in the area:

Museum of Comparative Zoology, Harvard University
Amherst College
American Museum of Natural History
Yale Peabody Museum
Princeton University Museum
Philadelphia Academy of Sciences
Carnegie Museum
Iowa State University
Alf Museum, Webb School
United States National Museum
University of Kansas Museum
University of Nebraska State Museum
University of Wyoming Geology Museum
University of Colorado Museum
University of California Museum of Paleontology
(Lillegraven and McGrew, 1976)

Specific geological formations containing fossils or a high potential for them in the area include Tatman Formation, Willwood Formation, Polecat Bench (Fort Union), and Lance Formations.

"Known collections from the fossil-rich Willwood Formation constitute one of the most significant, if not the most significant, samples of early Eocene mammals and reptiles in the world" (Lillegraven and McGrew, 1976).

The Bureau of Land Management has two active permits to conduct scientific paleontological investigations in the area. One is to Yale University's Peabody Museum and the other is to Wyoming University's Department of Geology.

Prehistorical Resources

Background Wyoming, as an arbitrarily bounded area, has known the existence and the influences of many cultures. For more than 12,000 years man has lived here. Earlier cultures gave way to somewhat different ones, and through time and various cultural influences, especially from the southwest, northwest and the east, gradual change occurred.

The northwest plains, a large and regionally general archaeological cultural area, which includes portions of Wyoming, has a timeframe and cultural sequence developed by William Mulloy of the University of Wyoming. His chronological framework (Figure 16) will be used to help show man's existence in Wyoming, and especially the Big Horn Basin, where the subject lands of this report lie. It should be remembered that the time periods are broad and often vague in nature and do not necessarily indicate abrupt changes in man's life styles. Change was generally slow and different sequences are more accurately understood as a continuum.

The timeframe is as follows: The Paleo-Indian period from the earliest evidences of man in the area to approximately 7000 years before present (B.P.), the Altithermal, 7000 B.P. to 4500 B.P.; the Early Middle and Late Middle Prehistoric, 4500 B.P. to 1500 B.P.; Late Prehistoric, 1500 B.P. to 300 B.P. or Historic (Mulloy 1958).

The Big Horn Basin is a large area in northwestern Wyoming and all of the subject lands (1,417,000 acres) are found within it. The Basin has provided habitat for man for more than 12,000 years. The earliest time period, Paleo-Indian, is represented first by the artifact variety known as Clovis or Llano. A recently excavated site near Worland contained Clovis-like tools associated with the remains of several mammoths, an early form of elephants. Both the mammoth and the Clovis culture became extinct at about the same time.

The Folsom tradition is a cultural variety somewhat more recent than Clovis, which was present in the Basin also. Folsom artifacts have been found near Shell. A partial excavation of this site was done in 1975 by the University of Wyoming. Many tools were located which are representative of these men who hunted a large and early form of bison. The Folsom culture seems to have disappeared some 10,000 years ago.

Members of later cultures, Plano, also were big game hunters and they became extinct, along with the large bison they hunted, about 7000 B.P. The Big Horn Basin contains a major site of the Plano tradition, the Horner Site near Cody. This site has yielded many artifacts bearing the name of "Cody Complex." Medicine Lodge Creek, a stratified site that contains many cultural levels, is located near Hyattville and displays artifactual evidences of these early cultures.

About 7,000 to 4,500 years ago the overall climate of the region became somewhat hot and arid. This period is called the Altithermal. Sites relating to the Altithermal are rare and those that represent this period reflect a diminished population or a more infrequent use of the area. Altithermal sites have been located in the Basin. Two important sites include Medicine Lodge Creek and Mummy Cave (40 miles west of Cody).

After the Altithermal, various cultures appeared which make up what is known as the Middle Prehistoric Period. These people were hunters and foragers. The beginning cultures of this period are referred to as the Early Middle Period, which includes the McKean Complex. This complex has been found on both the western and eastern sides of the Basin—the Mummy Cave site near Cody and the Leigh Cave site a few miles east of Ten Sleep. The later cultures of Middle Period are referred to as the Late Middle Period. Sites from this period date from about 2500 to 1500 B.P. Two sites which represent the Late Middle Period are Rabbit Bone Cave on the western side of the Basin and Spring Creek Cave near Ten Sleep on the eastern side. The Big Horn Mountains contain many sites from the Middle Period.

The Late Prehistoric Period (approximately 1500 to 300 B.P.) is exemplified by many sites in the Big Horn Basin. The following are two sites representing this period—the Crooked Creek site and Canyon Creek Butte site. Both are stone circle sites containing evidences of pottery. Horses and the bow and arrow also came into use at this time. Bison jumps are often associated with this period. A site of this type, where the animals were forced or stampeded over steep cliffs, has tentatively been identified in the northeastern part of the Basin. Many other sites of this period can be found throughout the area.

The Historic Period (300 B.P. to 100 B.P.) in the Basin area includes many cultures which inhabited various places for various lengths of time. Much of northwestern Wyoming "was occupied either permanently or intrusively by northwestern plains groups—with Crow, Shoshoni, and Arapaho being the most evident," (Zeimens, Wilson, Larson, Miller, and McQuire, N.D.).

Archaeology The area included within the boundaries is relatively unknown to archaeologists. Research of literature and consultation with an archaeologist quite familiar with the Big Horn Basin, Prof. George Frison of the University of Wyoming, indicate that even though many sites are known in the fringe areas of the Basin, not much is known about the archaeology of the central portions (Frison 1975).

At least two systematic inventories have been conducted within the area. The first (1975) and largest (approximately 15,000 acres) was conducted by the Bureau of Land Management, Worland District. This was done to help determine the existing environment for an environmental analysis on the proposed agricultural development known as "The Westside Irrigation Project." The other investigation (600 + acres) is the *Archaeological Survey of Grass Creek, Hot Springs County, Wyoming* conducted by Montana College of Mineral Science and Technology Foundation, Mineral Research Center.

A total of 12 sites was located on the Westside lands. All of those were small, shallow surface sites. Two sites were identified in the Grass Creek survey. One was a lithic scatter and the other a stone ring site. No diagnostic, dated artifacts were recovered from either site (Fredlund 1975).

A total of 46 sites is known to exist within the area boundaries and many more in nearby localities. The vast physical size of the area in question absolutely precludes a complete archaeological investigation prior to the writing of this report. Surveys of some 16,000 acres yielded 14 sites. The remaining 1,400,000 acres will yield a substantial but unknown number of sites when and if the area is completely surveyed. In reference to this matter the following comment should be considered relevant to the area:

> There is no way, of course, to predict exactly how many more sites remain to be discovered or to say what their importance will be. It can safely be stated, however, that a great many archaeological sites remain undiscovered in this area and that any portion of it has the potential for producing a highly significant site (Zeimens, et al., n.d.).[1]

The known sites constitute a variety of locales, types, and significance. They range from rock art to habitation sites, game lookouts, and quarry sites containing lithic raw materials used to make stone tools. At least one site is of very high significance and is currently listed in the National Register of Historic Places (Legend Rock Petroglyph Site near Grass Creek). Many other sites may exist which could qualify for future enrollment in the National Register.

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[1]This comment was made about the entire northwestern section of the state which the subject lands of this report lie well within.

Historic Historic sites are known to exist on the subject lands. In corresponding with the Wyoming Recreation Commission, the following list of historic sites of concern was compiled for this report:

- Bridger Trail (see Map 9)
- Red Lodge-Fort Washakie-South Pass-Green River City Stage Route (see Map 9)
- Embar Ranch and Post Office (31 miles west of Thermopolis on the Owl Creek Road)
- Town of Gebo (T. 44 N., R. 95 W.)
- LU Sheep Company or Baxter Ranch (36 miles northwest of Thermopolis on State Highway 120)
- Old Town (six miles north of Thermopolis on State Highway 789)
- Legend Rock Petroglyph Site (Cottonwood Creek)[1]

These sites listed above which are not enrolled in the National Register "are listed in the Wyoming Inventory of Historic Sites which may qualify (them) for future enrollment in the National Register" (Frost 1976).

The two historic roads are roughly drawn on Map 9 and may not exactly represent the locations in all places.

> "The Red Lodge-Fort Washakie-South Pass-Green River City Stage and Mail Road . . . varied slightly from time to time as post offices and other considerations changed. The consideration to be kept in mind is that where these historic roads went there will be found vestiges of cultural heritage—ranches, stage stations, difficult grades, stream crossings, etc.—which have not yet been listed on any register or in any inventory of historic places. Of course, the same is true—particularly of scattered, early-day ranches — throughout all of the area" (Frost 1976).

There is a lot of land included in this report about which very little cultural history information has been recorded (Frost 1976).

Socio-Economics

Nature of the Industry

Oil and gas production, insofar as it affects the local community, involves four phases: exploration, development, production (including transportation, refining, and marketing), and abandonment. Exploration is generally a low-keyed operation which employs crews from outside the region who patronize local motels, restaurants, and entertainment establishments, but who do not become residents. Even in the Big Horn Basin where most oil and gas related services are available, exploration is done by transient crews. The number of employees in the Basin may vary at any one time from 10 to as many as 50.

When exploration reveals reserves, exploratory or wildcat drilling is begun. If marketable oil is found, the well is completed and other wells are drilled to develop the field.

[1]This rock art panel is currently enrolled in the National Register of Historic Places.

Development, if extensive, requires a large capital investment to drill new wells, install tanks, and construct pipelines. This period may last several years and will require extensive labor imported from outside sources. Normally there are 50 to 75 employees on drilling crews, but if there is a "boom" this number can drastically increase. This period may, depending on the size of the development and the nature of the local economics, overtax the supporting infrastructure. Schools may have to be expanded, more houses built, and services increased to accommodate new residents.

However, the boom is not permanent. After development is completed, contractors and oil field workers must find employment elsewhere. What follows is a short period of relatively high unemployment, until workers find new jobs outside the region, and depressed real estate values. Also, there will be underutilization of schools and other public and privately owned facilities built or enlarged to accommodate the increased demand generated by oil and gas development.

Worland experienced this boom stage in the late 1950s and early 1960s, when the Worland and Nieber fields were developed. Housing values dropped and families who had acquired housing at premium prices were forced to sell their property at reduced prices.

The production phase is relatively stable, using local and imported labor. This is not a labor intensive phase. A large field such as Hamilton Dome may employ only 12 to 15 people. The Little Buffalo Basin, Grass Creek, and Hamilton Dome fields have been producing since before 1920.

Gradually the reserves are depleted and the field is abandoned. This phase is gradual; some fields are deactivated while others may be drilled to capitalize on remaining reserves. But, overall production declines and with it employment and personal income also decline. This decline is so gradual that it is unlikely to cause severe economic problems to the community. Actual labor involved in abandoning a well is supplied by production or service crews which are already employed.

All four phases of oil and gas production require a variety of services, almost all of which are available in the Big Horn Basin. Table 18 indicates the types of oil and gas services available in this region.

Oil and gas extraction shares many characteristics of other extractive industries in that it adds to the export sector of the local economy, meaning that the wages paid to those employed in this activity come from markets outside the region and constitute a net flow of dollars into the local economy. This stimulates employment in the secondary sector, that part of the local economy—medical, retail services, education, home construction—which serves the needs of those employed in the export sector of the economy.

However, there are several problems associated with oil and gas extraction. Quite often the jobs created cannot be filled by local personnel and require job skills from outside the area. It should be noted that these activities do not alleviate existing unemployment even though the number of jobs available is increased. Furthermore, extractive industries are generally more cyclical than most because of their sensitivity to national and international economic and political instability.

TABLE 18
Oil and Gas Services Available in the Big Horn Basin

Oil Field Equipment
Oil Field Equipment—Renting
Oil Field Hauling
Oil Field Service
Oil Field Specialties
Oil Field Supplies
Oil and Gas Exploration and Development
Oil Land Leases
Oil Pipeline Companies
Oil Producers
Oil Well Casing Pulling
Oil Well Cementing
Oil Well Coring Service
Oil Well Directional Drilling
Oil Well Drilling Contractors
Oil Well Drilling Mud and Additives
Oil Well Equipment and Supplies
Oil Well Fishing Tools
Oil Well Logging and Perforating
Oil Well Services
Oil Well Testing

The labor force required for oil and gas extraction demands public services such as schools, streets, water, and sanitation facilities with resulting increases in capital improvements. It is generally assumed that the taxes assessed against the industry and against the property of the employees will cover the cost of increased services and capital expenditures but, in the case of extractable minerals on federal lands, two things must be considered.

First, there are no assessed taxes on minerals extracted from federal lands, but the royalties provide comparable revenues to local units of government and add considerably to the state's revenue intake. By relieving a proportion of the state tax burden and a part of the local tax burden, royalties appear to make oil and gas extraction on federal lands highly beneficial to the fiscal health of the state and counties in which it occurs.

The second consideration is the duration of the activity. Any extractable mineral, assuming that the market and the quality of the mineral can be accurately assessed, may be expected to yield revenues and wages to the local economy on a predictable schedule. With this information, it would be possible to invest capital on streets, schools, and sewer and water facilities with the assurance that they could be amortized on a schedule congruent with the predicted revenue schedule. Unfortunately, neither the market nor the resource are always predictable, and generally communities faced with capital expenditures required by increased growth must consider the possibility of losing a substantial part of their revenue when the resource becomes either depleted or unmarketable because of shifts in technology or the economy.

However, most contingencies discussed above are mitigated by several conditions present in the Basin. The oil and gas industry has been active in the region since before 1920 and, consequently, almost all necessary labor and services are locally available with the incomes being recirculated rather than lost to the local economy. Historically, there has been no sudden abandonment of fields in the Basin. In the 1950s, the Basin experienced its greatest boom in exploration and development. Indicative of this increased economic activity, the population peaked in the 1960 census, followed by a very noticeable decline by 1970. Big Horn, Hot Springs, and Washakie Counties experienced drops in population of 14, 22, and 15 percent respectively; Park County posted a very modest increase of 3 percent as compared to 11 percent the decade before.

Whatever the problems associated with oil and gas extraction, it provides the best per capita source of income. Table 19 compares income with employment in nine major groupings.

TABLE 19
Percentage Wyoming Employment Compared with Percentage Income[1]

	Percent Income	Percent Emp.	Comparative Income Per Employee
Agriculture	8.2	13.5	0.61
Mining (including oil & gas)	13.3	8.8	1.51
Construction	8.5	6.8	1.25
Manufacturing	6.5	5.2	1.25
Transportation and Utilities	10.5	8.2	1.28
Wholesale, Retail Trade	15.2	18.0	0.84
Finance, Insurance & Real Estate	3.5	3.3	1.06
Services	12.9	14.2	0.91
Government	21.1	22.0	0.96

[1]From Wyoming Data Book, Division of Business & Economics Research, College of Commerce and Industry, University of Wyoming, 1972

Mining provides the highest per capita income while construction, manufacturing, transportation, and utilities provide per capita income that is higher than the average for the Basin. Conversely, income from agriculture, wholesale and retail trade are quite low compared to the average for the Basin. What seems certain is that oil and gas employment is more lucrative than other activities.

Socio-Economic Profile

The lifestyle in the Grass Creek study area is predominantly rural. Agriculture is dominant in Washakie and Hot Springs Counties and is significant in Park County. Table 20 shows the employment for Big Horn, Washakie, Hot Springs, and Park Counties by percentage and rank as well as the mean percentage for all the counties in Wyoming. Because the study area includes parts of four counties, this data must be applied carefully to this analysis.

Big Horn and Park Counties are barely represented in areal terms and are not heavily influenced. Though many of the oil service businesses located in Cody, Powell, and Greybull almost certainly service these fields, they have work in other areas of the Basin and are not critically dependent on them. In 1974, the Elk and Oregon Basin fields in Park County (a few miles north of the study area), alone produced one and a half times as much oil as the entire study area.

Washakie and Hot Springs Counties are more directly associated with the study area. The City of Worland, with about two-thirds of Washakie County's population, is adjacent to the area. Most of Hot Springs County is in the area. Oil and gas service industries in Worland and Thermopolis are more dependent on these fields than are similar businesses in other parts of the Big Horn Basin.

Manufacturing employment is more important in the Basin than in other parts of the state. Washakie, Park, and Big Horn Counties rank first, second and third, respectively, in manufacturing employment. This could be expected to add a considerable degree of stability, particularly since the activity is diversified rather than centered on one type of product. Construction and transportation employment is less than the state average in all four counties, though Worland has experienced rapid growth since this data was compiled. Service employment is important in Hot Springs County, reflecting the very successful tourist and retirement industry centered around the hot springs in Thermopolis and perhaps a higher than average presence of transient exploration crews. Under these circumstances, service activities function as an export activity in that they cause a net flow of dollars into the economy.

The total employment picture for the other three counties is one of an adequate and diversified base economy consisting of agriculture, mining, and manufacturing.

TABLE 20
Percent of Employment by County

	Big Horn County		Washakie County		Hot Springs County		Park County		Wyo. Counties Mean	Wyo. Percent State Workforce 1970
	Rate	*Rank*	*Rate*	*Rank*	*Rate*	*Rank*	*Rate*	*Rank*		
Unemployment	5.60	3.0	4.60	7.5	4.30	11	4.40	10	4.27	—
Agricultural	24.19+	6.0	20.27+	8.0	10.71-	16	14.85-	12	16.19	14
Mining	6.38-	14.0	3.50-	16.0	9.09+	8	7.31-	11	7.80	9
Construction	5.54-	16.0	6.99-	8.0	6.62-	12	6.55-	13	7.26	8
Manufacturing	9.38+	3.0	12.31+	1.0	1.21-	22	9.49+	2	5.40	5
Transportation & Utility	6.45-	13.0	6.81-	10.0	67.20-	11	5.01-	18	7.36	8
Trade	15.74-	22.0	19.15-	16.0	18.94-	17	20.36+	11	20.12	18
Financial	2.64-	19.0	2.92-	14.0	3.38+	7	3.10-	10	3.15	3
Service	9.34-	19.0	12.31-	12.0	21.11+	2	14.70+	7	13.67	14
Government	20.34+	6.0	15.81-	16.0	22.22+	5	18.63-	9	19.20	22

(Note: + or - after rates indicates whether they are greater or less than Wyoming Counties mean.)
(Source: Wyoming Socio-economic Data; Center For Social Research and Development; University of Denver.)

FIGURE 11. Scenic overlook along Highway 431.

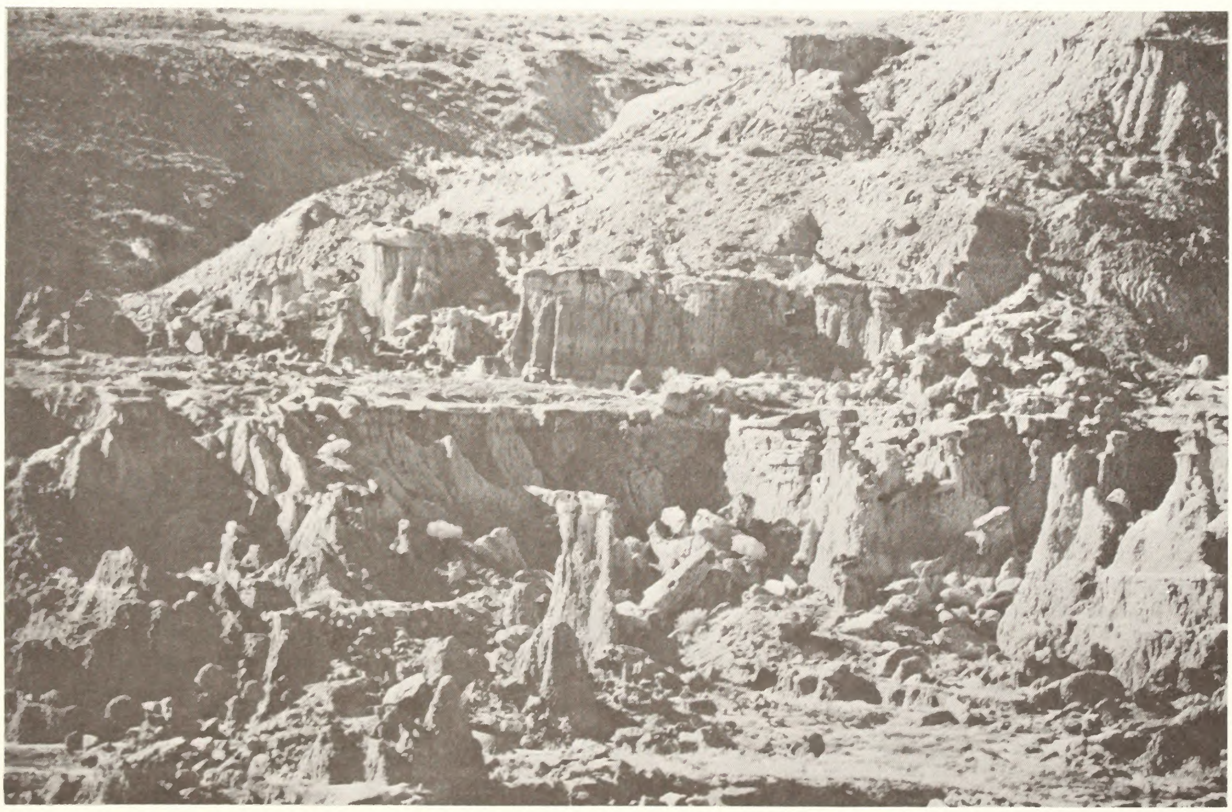

FIGURE 12. Badlands along Highway 431. These lands are susceptible to severe erosion.

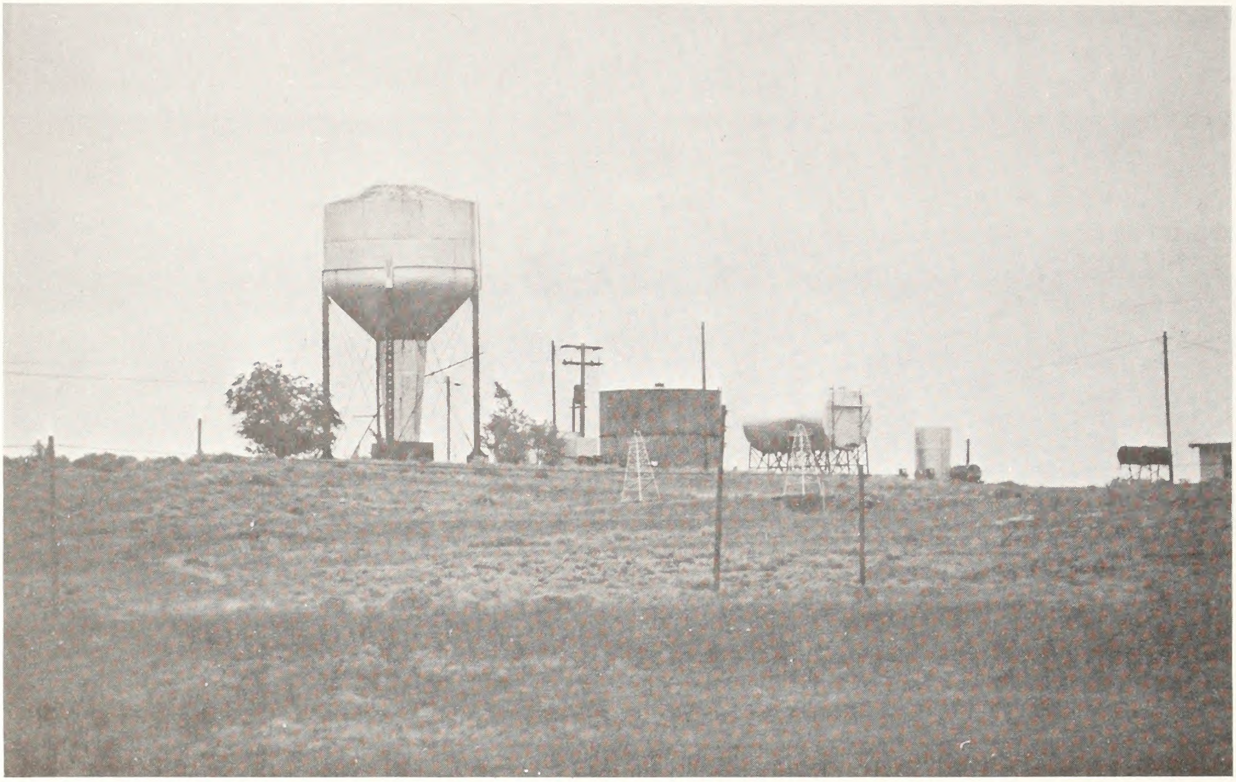

FIGURE 13. Oil facilities typical of Big Horn Basin—showing middle ground and skyline intrusion (Hamilton Dome oil field).

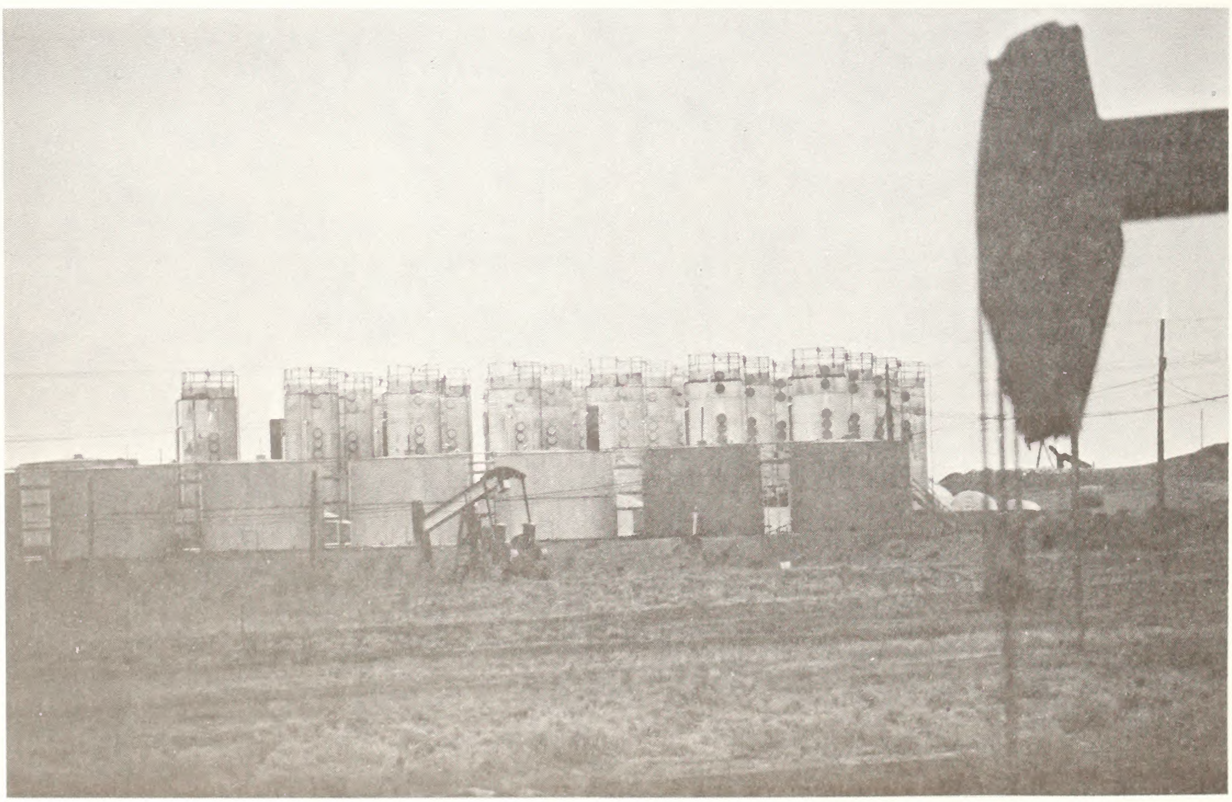

FIGURE 14. Oil treaters in Hamilton Dome oil field.

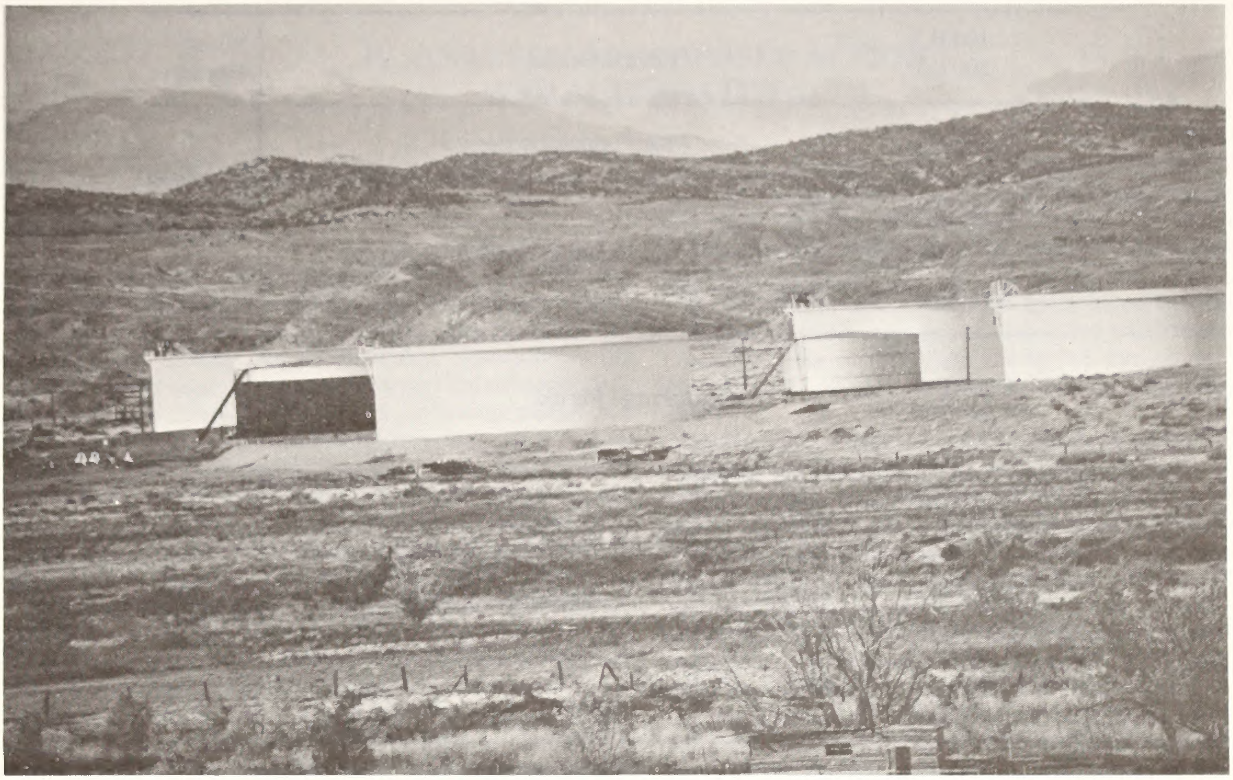

FIGURE 15. Oil storage tanks of the Platte Pipeline near Highway 20 south of Worland.

100 B.P. 300 B.P.		Historic Period	Bison Hunters
1,500 B.P.		Late Prehistoric Period	(Archaic) Hunters Foragers
2,500 B.P.	Late	Middle Prehistoric Period	
4,500 B.P.	Early		
5,000 B.P. 7,000 B.P.		Altithermal Period	
8,000 B.P. 10,000 B.P.	Plano	Paleo Indian Period	Big Game Hunters
11,000 B.P.	Folsom		
11,500 B.P. 12,000 B.P. 13,000 B.P.	Clovis		

FIGURE 16. General prehistoric culture outline[1].

[1]Mulloy, William (1958)

IV. ANALYSIS OF PROPOSED ACTION AND ALTERNATIVES

ANTICIPATED IMPACTS

Air Quality

Activities resulting from oil and gas leasing, such as exploration, development, production and ultimate abandonment do have an effect on air quality. Dust raised during road and drilling pad construction, especially during dry and windy conditions, increases particulate concentrations in the air. The contribution of particulate matter as a result of the initial surface disturbance is generally small compared to that resulting from continued use of access roads by oil field maintenance personnel, ranchers and farmers, and by the general public for recreation. To a lesser degree, smoke from internal combustion engines, especially diesel engines, contributes to particulate loading.

While exploration affects air quality over a broad area, development results in air pollution over a small area. The primary air pollutants during the development stage are dust from vehicular activity around the drill pad site, on access roads to the site, and smoke and other emissions from vehicle and stationary engines used in the drilling operation. In the production phase, air pollutants such as carbon monoxide, hydrocarbons, nitrogen oxides, sulphur oxides, and hydrogen sulfide are produced in separation facilities; during disposal of liquid waste and unwanted gas; by burning of waste petroleum products; by emission of objectionable odors; and by venting of noxious vapors from storage tanks. Also in the production phase, accidental explosions, fire, blowouts, oil spills, and leaks can occur, causing potentially serious air pollution problems.

Abandonment of an oil and gas well or field ends the direct air contamination resulting directly from oil and gas operations, but continued use of roads and trails by the public will produce dust in the area for years.

Soils

Environmental impacts upon soils should be considered under two major categories: compaction and disturbance.

Compaction

Compaction has been described as a serious potential cause of reduced vegetation production and erosion. The measure of compaction is bulk density (ratio of weight under water to weight in air). It occurs when a compressing weight at the surface causes some spaces in the soil to collapse. The soil then becomes more dense. This most often occurs when a zone layer below the surface of the soil is saturated with water after a rain or snowmelt period when the surface appears dry. Once this zone is compacted, it may never return to its normal state. Compaction of soil by trucks or other heavy equipment passing repeatedly over the soil severely limits vegetation production to the point of sterility. Old trails and access roads which have not been travelled for years often show no vegetation growing in the tracks due to the effects of a compacted layer in the subsoil.

At the present time, there is no quantitative information available as to the amount of suspended particulates produced per acre of disturbed soil in the study area. Similarly, quantified data on gaseous emissions are not available.

Preliminary exploration for oil and gas which involves hundreds of miles of seismic lines and thumper and vibrator methods that pound or vibrate the earth to create a shock wave will cause compaction to some extent on several hundred acres annually. The amount of compaction and the resulting impact will vary greatly with the soil type and climate zone involved. The impact will be most severe when the soils have been saturated and are in the process of drying out. This occurs in Soil Area "C" most frequently during spring and early summer, and is least likely to occur during the fall and in early winter with light, late snowfalls. Soil Areas "F" and "M" are most susceptible to compaction during early spring and when winter thaw periods occur. On most soils, compaction will result in a decreased infiltration rate and thus increase runoff during precipitation events. In some cases, this increased runoff will result in accelerated erosion on areas downslope of the compacted area.

Disturbance

Soil disturbance leaves the ground barren at the point of disturbance and affects adjacent areas. Erosion by wind and water is a serious problem on many parcels of the area as it now exists. This erosion problem is increased when the areas are disturbed by such actions as the construction of drill pads and access roads. These areas are more susceptible to erosion because of the increased volume of dislodged soil particles which can easily be moved by wind or water, and because the thin layer of soil that exists to give a mantle of some protection to the surface has been broken. Soil surveys with sufficient detail to delineate the erosion potential within the area are not available, and the impact on any given portion of the area cannot be quantified. However, erosion potential of any soil increases with the amount of slope. Areas which are now showing symptoms of accelerated erosion, such as rills and large areas of sheet erosion, will be most seriously impacted by any soil disturbing activities.

Major land areas have evolved soils that have the ability to take moisture at a certain rate, store the right amount of water in relationship to native plants grown, and protect themselves to a degree against unusual storms. Some of these areas receive additional moisture in the form of

runoff from adjacent areas, and the soil forming processes now occurring are dependent upon that moisture.

Once an area has been disturbed, the soil forming processes unique to that area as well as to adjacent areas may not be able to continue. Erosion of gullies and channels may be accelerated, or worse yet, new gullies and channels may be created. For example, a road, track, or single trail crossing a land form on the contour becomes a water diversion structure across that natural area. The structure stops the overland flow of water and collects it to the natural drainages higher up on the watershed than has normally occurred. The water diverting nature of a disturbed area then affects the moisture runoff to adjacent areas.

Areas of disturbed soil in soil associations "FF" and "M" will expose concentrated amounts of soluble salt at the surface. The movement of the surface particles caused by wind and water erosion will redeposit these salts over adjacent areas, thereby raising the soluble salt concentration at the surface in the adjacent areas. Again due to the lack of detailed soil surveys as well as site specific proposed action components, it is not possible to quantify the impact of soil disturbance upon adjacent areas.

Geological Structure

General

Geological values are susceptible to alteration and destruction as the result of all phases that can destroy or impair their values as human interest subjects. Activities using explosives in the vicinity of delicate geological features, such as cave formations or erosional arches, can destroy or impair their interpretive value. Activities involving earthmoving can produce similar effects on unique geologic features.

Placing of development structures in close proximity to geological features of interest tends to distract from their value for viewing and interpretive purposes.

Geological Subsidence

Geological subsidence is an impact which can occur under certain conditions during the production phase of the operations. In a closed reservoir, where the fluid-holding rock is poorly consolidated, the removal of fluids and gases will leave void spaces unfilled, resulting in the compaction of rock (from the weight of the overburden). The surface expression of this compaction is called subsidence. The amount of subsidence at the surface is equal to the amount of compaction of the compressed layer. Within oil fields, the depletion on producing zones 2,000 to 4,000 feet deep or more may cause compaction to occur in the sands, depending on their physical character and mineral content. This phenomenon was first observed in Texas in the early 20's at the edge of Galveston Bay. Several square miles subsided three or more feet, with cracks appearing in the ground within the Goose Creek oil field.

In areas where natural gas is dissolved in subsurface groundwater, the withdrawal of the water has caused significant subsidence. The solubility of natural gas in salt water is low; therefore, large volumes of water must be pumped to obtain a large quantity of gas. Accumulating evidence indicates that under total stresses applied to unconsolidated heterogeneous deposits in overdrawn groundwater basins, most of the compaction is in the fine-grained impermeable zones adjacent to the aquifer zone.

USGS studies have shown through sensitive measurements, that subsidence begins within a few minutes after the first withdrawal of subsurface fluids.

Seismicity

There are instances where earthquakes may be triggered or caused by drilling when fluids under pressure penetrate or lubricate shaley formations that are under tectonic stress or strain.

Blowouts may conceivably cause earthquakes by injecting fluids under high pressure into formations under tectonic stress; however, there is little historic data to substantiate such events. Subsidence can also result from naturally occurring earthquakes causing settlement in unconsolidated sedimentary rocks or offsetting zones of weakness in surface rocks.

There is little historic evidence to indicate that injection or withdrawal of fluids during drilling and producing operations cause earthquakes. Several cases of subsidence, however, are known to have been caused by withdrawal of oil and gas. Drainage to surrounding structures resulted; but, generally, the effects were limited to the central producing area.

Minerals

Well facilities, storage tanks, separation plants, pipelines, and operation buildings may preclude mineral development in these areas during the productive life of the field.

Land Use

Ranching

Construction of roads, pipelines, drill sites, and production facilities affects ranching operations. All of these activities cause surface and vegetation disturbance, taking small amounts of land out of forage production. Vehicle use on roads can result in injury or death to livestock on or crossing roads. Drilling mudpits and treater water skimmer pits are hazardous to livestock, in that livestock can become mired in the mud or drown in the water in the pits. Unpleasant odors and toxic gases from nearby producing wells and treatment facilities can be obnoxious or lethal to residents and livestock. Noises from oil and gas activities can be irritating to some residents. Accidents

around wells and storage facilities resulting in explosions and fires can be hazardous to people and livestock.

Road construction can facilitate the rancher's supervision of his livestock operation by providing easier vehicle access to his grazing lands. Produced water from some oil and gas wells can be put to beneficial use by ranchers for livestock water and irrigation of hay meadows.

Farming

Oil and gas activities can take prime agricultural lands out of production for long periods. The impact on agricultural lands is much more significant than that on grazing lands having lower productivity. Farm field operations, such as tillage and irrigation, can be disrupted by location of wells and other facilities in a field. Irrigation systems may have to be modified drastically for such facilities. Burning of crop residues, a common practice in the study area, could be prohibited due to the obvious danger to oil and gas production facilities located on or adjacent to agricultural lands.

Minerals

Sand and gravel are needed for most oil and gas activities for surfacing roads and areas around well sites and production facilities. Increased production of those minerals involves additional surface disturbance for sand and gravel pits and access roads to those pits. Of course, hauling of those materials involves increased road use. Depletion of sand and gravel reserves is also another impact. Local sand and gravel and road contractors benefit economically from the oil and gas operations' need for sand and gravel.

Mining of bentonite within the Big Horn Basin is affected by oil and gas activities in that bentonite is used in oil and gas well drilling mud. Some of the surface disturbance from bentonite mining can be attributed to the oil and gas industry's need for bentonite. Bentonite mining companies obviously benefit economically from this need.

Transportation

Additional roads are constructed for most new oil and gas activities in the area, with most being solely for use in exploration, development, and production of new oil and gas deposits. The roads may or may not be used by recreationists, hunters, ranchers, and others. Roads used to haul produced oil from the fields need to be constructed for all weather use. Alignment and grade of those roads needs to be conducive to rapid transportation. All of these requirements mean increased surface disturbance. Long-term use of the roads also increases hazards to livestock.

Powerlines and pipelines are needed for oil and gas production activities. Pipeline companies and power companies are called upon to construct facilities used for oil and gas production, which increases their revenues. At the same time, those companies may be required to expend capital for construction of additional facilities to supply electricity and transport additional oil and gas.

Communication facilities such as telephone and radio are necessary for oil and gas activities. This involves expenditure of funds and manpower by private telephone companies and various state and federal agencies for such requirements as radio repeater sites, channel assignment, and licensing.

The impacts on the Burlington Northern Railroad from oil and gas activiites in the area are apparently beneficial, requiring transport of oil field equipment and petroleum products. Existing track and rolling stock are probably adequate to serve the oil and gas industry in the Big Horn Basin.

Residential/Commercial/Industrial

The major towns within the study area experienced an oil boom during the 1950s and somewhat of a bust in oil and gas activity during the 1960s. Oil and gas booms cause rapid fluctuations in prices of real estate, housing, goods, and services. As a result, overbuilding and land speculation occur. Most towns, such as those in the study area, are seldom prepared to handle these boom town problems. Most have no comprehensive land use plans, little money, and little or no experience in anticipating the problems or handling them once they arise. Without comprehensive land use planning or zoning, conflicts result such as commercial and industrial uses within residential areas, strip development, improper siting, scattered development, and development of physically unsuitable lands.

Revenues, royalties, and taxes from the oil and gas industry and other mineral industries are the major source of income for state, county, and local governments in Wyoming. This income is probably the reason that the state residents pay no state income taxes, a tangible benefit to all taxpaying citizens of Wyoming.

Timber

Oil and gas actions take forest land out of production and sometimes constrain timber harvest and reforestation. On the other hand, physical access to many of the timber stands in the area is a problem. With small scattered stands being the rule, the cost of road construction into timber areas may make it uneconomic to harvest the timber. Roads constructed by the oil and gas industry sometimes make it economically feasible to harvest this timber and place these stands under management.

Water

The environmental impacts upon the water resource result from each of the discrete actions associated with oil and gas leasing.

Preliminary Exploration

The impacts to the water resource which occur in the preliminary exploration phase are the following.

Erosion and Sediment Yield During the preliminary exploration phases, several types of on-the-ground seismograph surveys are made. New access trails are required for the movement of heavy equipment. Recent cooperation between the BLM and seismograph companies concerning the placement of access trails and the amount of bulldozer work has reduced the amount of erosion and sediment yield from seismograph trails. New trails, however, are still responsible for a considerable amount of erosion and sediment yield. No satisfactory method was found for estimating the amount of sediment produced from access trails. (See Figures 17, 18, and 19.)

Field observations indicated that the most severe problems occur where the trails cross stream channels. (See Figures 20 and 21.) Streambanks are generally unstable; once the vegetation has been disturbed, revegetation is difficult. All eroded sediment enters the stream channel and within a short time enters a live body of water. The direct result is an increase in suspended sediment and turbidity. It is estimated that 17.25 acres of stream channel are disturbed annually from seismograph activity.

Erosion is also accelerated along any steep sloping terrain which has been disturbed by seismograph activity. (See Figures 22 and 23.)

During the preliminary exploration phase, much of the earth-moving work is completed. The greatest impact on the water resource is the increased turbidity, concentration of sediment, and total sediment yield. The amount of sediment produced from oil and gas activity, however, could not be quantified.

Exploratory Drilling

Erosion The drilling of exploratory wells requires roads which are of a more permanent nature than access trails for seismograph exploration. These roads are completely stripped of vegetation, exposing the soil. Erosion from these roads is evident, particularly where the slopes are greater than 15 percent. Soil composition and precipitation patterns play a key role in determining erosion rates. Estimates for determining erosion rates must be site specific.

Drilling platforms are also subject to erosion. (See Figure 24.) Often, on sloping terrain, cuts are made to construct a level drilling platform. Erosion rates from the cut banks and the fill slopes are increased over those on adjacent natural terrain.

Mudpits must be constructed before drilling. These mudpits are located within the platform area or adjacent to it. Erosion along the outside of the pits is often evident.

Water Requirement Permits to use water within the State of Wyoming are issued by the State Engineer's Office. This permit is not an exclusive right to use water. It only means that the operator can use the water if the surface owner will allow the operator to enter onto his surface and remove the water from a specific source. BLM reviews these water haul areas on public lands and states whether or not the operator can use the water. Enough water must remain to accommodate other resource needs.

Water is mixed with various substances to make the drilling mud. In certain areas, this water may be supplied from a nearby reservoir, stream, or in some cases a separate water well may be drilled. The withdrawal of this water for the drilling operation in the past has created no known conflicts in the Grass Creek area. The amount of water needed for the mudpits is not of sufficient quantity to deplete most water supplies. It should be noted, however, that in areas where there is substantial drilling, the diversion of water for this use may conflict with other water uses. If a problem develops, it will have to be resolved by the State Engineer if water rights have been filed on the water supply.

Ground Water Contamination At a given depth, the true water table will be reached. From this point, each formation below the water table will have water in it. The quality of the water in each formation varies. A fresh water formation may, for example, exist above or below a briny water formation. Presently, there are regulations to prevent interformation contamination. These regulations include cementing the surface casing to a depth of 100 to 1,000 feet. The oil companies are also required to cement 100 feet above and below the producing zone. In special circumstances, oil companies are also required to cement other formations. This would be the case in particularly high water yielding formations. In the study area, the Madison Formation — and possibly the Ten Sleep — are the only high yield formations that would fall into this category. Oil well drilling, however, does not take place below the Madison Formation; and, therefore, this formation does not need to be cemented.

There are, however, instances where the cementing is not completed properly or where the casing breaks. In these instances there is an interformation mixture of waters. A significant impact could result when the interformation mixing consists of a briny water zone mixing with a fresh water zone. This might degrade the water quality in the fresh water zone. In the study area, this does not appear to be a significant problem. Many of the formations are low yield with relatively poor water quality. Intermixing of waters from these formations would not have a significant impact. The Ten Sleep and Madison Formations do yield substantial quantities of water. This water is generally of good quality and would be unlikely to contaminate another formation. High water yields from these formations would hamper oil production. It is, therefore, in the interest of the oil companies to correct any problems which result in high volumes of water leaking to the bore hole. It is estimated that about five percent of all oil wells will at some time face problems relating to interformation leakage. This would result when the cementing is not properly completed or in instances where the casing breaks. Steps are then taken by the oil companies to correct these problems. Interformation mixing or contamination is not seen as having a significant impact in the study area.

FIGURE 17. Old seismograph trails leave their scars upon the landscape. Revegetation has not completely removed the trace of the seismograph line even after a number of years.

FIGURE 18. The old and new. Seismograph trail to the left is many years old but is still visible. The newer trail to the right did not maintain a perfectly straight path and will be less visible in a number of years.

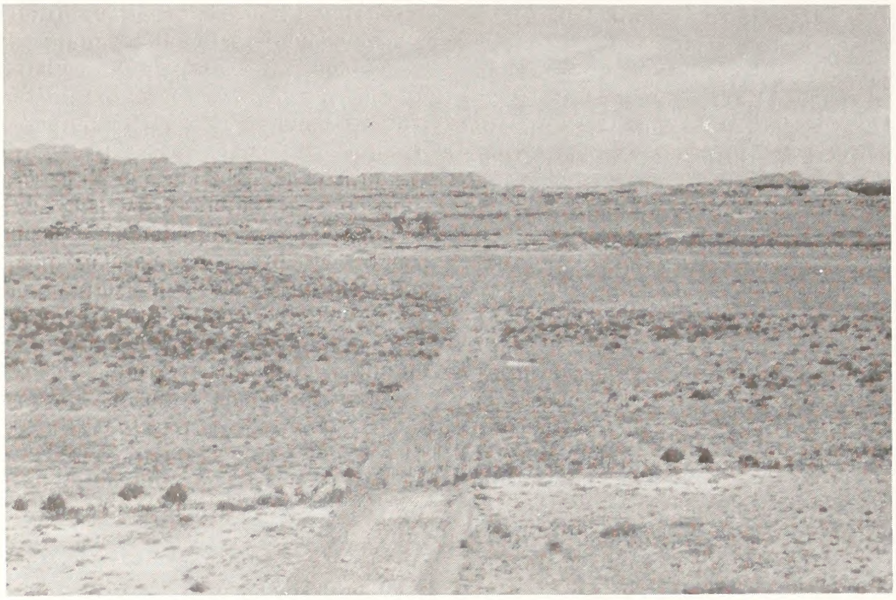

FIGURE 19. Newly completed seismograph trail. This trail has been reseeded with crested wheatgrass which will reduce erosion but will be visible for many years until native vegetation takes over.

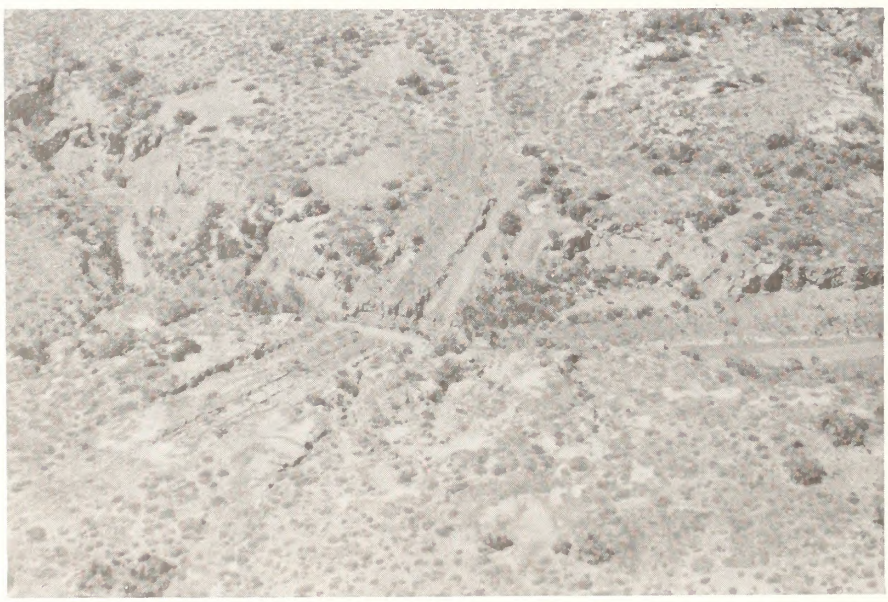

FIGURE 20. Old seismograph trail across ephemeral drainage. Note lack of revegetation along stream bank, and gully erosion.

FIGURE 21. Old seismograph trail across ephemeral drainage. Note lack of revegetation along streambank.

FIGURE 22. Seismograph trail. Note gully erosion throughout trail. No rehabilitation, extensive earthmoving.

FIGURE 23. Seismograph trail in extremely inaccessible terrain. No rehabilitation, extensive earthmoving.

FIGURE 24. Oil well platform with mudpit, graveled road and extensive earthmoving work completed. This new pit does not exhibit erosion yet, but unless revegetated, this site will be cut with deep gullies within a few years.

Mudpit Discharge After the well has been completed, the fluids in the mudpits are discarded. Generally, the pits are fenced and the fluid is allowed to infiltrate into the soil for approximately six months to a year. Observation indicates that very little of the fluid is absorbed by the soil. New Department of Environmental Quality regulations prohibit the disposal of mudpit fluids into drainages. Generally, the mudpits are buried with fluid in place or the fluid is pumped out and spread on the rangeland. These fluids nearly all exceed DEQ criteria for discharge; in some categories they are several hundred percent in excess of limits (Table 21).

The impact from the discharge of these pits is in most cases minor, unless the fluids enter a live body of water. It is not known what impact results when runoff carries the mudpit materials which were spread onto the range into live bodies of water.

Development

Erosion and Sediment Yield The installation of pipelines, tank batteries, and permanent access roads increases erosion and sediment production. As stated earlier, no satisfactory method was found of quantifying the impact from these actions.

Rock Fracturing Fracturing the producing zone is often part of developing a well. This process consists of opening up small fractures in the producing rock and pumping sand into them. This process aids in directing the flow of oil to the well bore hole, thus locally increasing the permeability of the rock. Improper fracturing might cause interformation contamination. This is not known to have happened in the Grass Creek area.

TABLE 21
Mudpit Analysis[1]

	Location				
Tests	T45N R92W Sec 26	T48N R92W Sec 33	T53N R100W Sec 14	T47N R93W Sec 27	T56N R101W Sec 8
Sulfates mg/l	8466.6	—	7280.7	—	1000.0
Sulfide mg/l	—	—	—	—	289.0
Chlorides mg/l	191.8	230.2	27.4	323.4	2499.1
Chemical Oxygen Demand (COD) mg/l	310.0	—	20000.0	—	—
Phenol mg/l	0.06	—	3.36	—	—
Oil & Grease mg/l	7.20	2587.0	—	1390.0	39.9
Total Dissolved Solids mg/l	4526.0	—	—	—	3840.0
Conductivity millimhos/cm	—	—	—	50.0	—
Boron ppm	—	0.45	—	11.10	—
Potassium ppm	—	121.0	—	639.0	—
Phosphorus ppm	—	4.0	—	3.0	—
Nitrate ppm	—	2.5	—	—	—

[1]Data collected by BLM and analyzed by Northwest Analytical Laboratories, Powell, Wyoming.

Production

Oil Spills The most severe impact associated with the production phase is the oil spill. Oil spills generally occur when the petroleum is in transit, but may also occur as blowouts during exploratory drilling and development stages. All oil spills are reported to the EPA and the State DEQ. These agencies are responsible for investigating oil spills. Fines may be imposed if negligence is involved.

Since July 1975, 16 oil spills have occurred in the study area, ranging from 25 to 54,000 gallons. No significant lasting environmental impacts were associated with the spills, according to DEQ (personal contact with DEQ personnel, Cheyenne, Wyoming).

It is estimated that between 15 and 20 oil spills will occur in the Grass Creek area annually. Although generally small in magnitude, the possibility exists for a major spill.

An oil spill entering a live water body could have a significant and long-lasting effect. The oil might render the water unsuitable for domestic, wildlife, livestock, agricultural, and industrial uses. The impact from a spill — if unchecked — could extend miles throughout many drainages.

It is not feasible to analyze the probability or the impacts of spills occurring at each KGS. There are, however, nine oil fields within one mile of perennial streams. (See Map 1.) A spill from these fields would have the greatest chance for imparting a significant impact upon the water resource.

Reinjection Water The water that is separated from the oil (treater water) is either reinjected underground or discharged into drainages. (Refer to Table 4.) Presently, there are 6.83 million gallons per day (mg/d) reinjected. Because of the increased use of secondary recovery methods, this figure is estimated to increase to 10 mgd by 1981. Regulations state that the reinjected water must be introduced into a subsurface horizon containing water of equal or poorer quality. In many cases, it is reinjected into the producing zone from which it came. There are no known instances where oil field waters were injected into fresh water aquifers in the Grass Creek area. Should such a situation occur, it would deteriorate the quality of the fresh water aquifer.

Discharge Waters All oil field discharge waters are regulated by the DEQ through a permit system. Presently there are 9.89 mgd discharged into drainages in the study area. It is estimated that an increase of 0.1 mgd to 0.3 mgd will take place annually for the next five years. New federal regulations, however, may curtail future treater discharges.

Existing discharge water has two significant impacts on the water resource. It reduces water quality and increases the amount of streamflow in all affected drainages.

Reduction in surface water quality is most pronounced in Cottonwood Creek. The treater water discharge into Cottonwood Creek is 12.4 cubic feet per second (cfs). The mean streamflow from 1941 to 1945 was 35.4 cfs. This indicates that on a yearly basis about one-third of the streamflow comes from oil fields. During the summer, over one-half of the streamflow may be attributed to oil field discharge.

Although water quality data are sparse, it is estimated that in Cottonwood Creek, annually, oil field waters increase the bicarbonate concentration by 250 milligrams per liter (mg/l); the chloride concentration by 150 mg/l; the sulfate concentration by 390 mg/l; the sodium concentration by 190 mg/l; the potassium concentration by 30 mg/l; the calcium concentration by 120 mg/l; the magnesium concentration by 30 mg/l; the boron concentration by 1.2 mg/l; total dissolved solids by 1,180 mg/l and oil and grease concentration by 2 mg/l. Also, the treater water discharge is directly responsible for an increase in suspended sediment of 50 to 200 mg/l. The effect of increasing the concentration of these constituents in Cottonwood Creek is to degrade the water to the point where it would not meet 1962 public health drinking water standards. During the summer months, treater discharge degrades water quality to an even greater extent. It should be pointed out, however, that a halt to the discharge of oil field waters would not alone necessarily guarantee potable water throughout the entire drainage, but would certainly lessen the impacts upon aquatic organisms. Other uses of the water — particularly irrigation — also degrade the water quality of Cottonwood.

Gooseberry Creek is likewise degraded by oil field discharge water, but to a lesser degree than Cottonwood Creek. The treater water discharged into Gooseberry Creek is 0.7 cfs. Existing data (1941-1953) indicates the mean discharge of Gooseberry Creek at the mouth was 13.7 cfs. This indicated that on a yearly basis about five percent of the streamflow in Gooseberry Creek can be attributed to oil field discharge. It is estimated that the oil field waters increase the bicarbonate concentration by 30 mg/l; chloride concentration by 20 mg/l; potassium concentration by 0.5 mg/l; calcium concentration by 15 mg/l; magnesium concentration by 0.5 mg/l; boron concentration by 0.1 mg/l; total dissolved solids, 160 mg/l, and oil and grease concentration by 0.1 mg/l on an annual basis. This reduction in water quality does not curtail any known beneficial use of the water.

Oil field waters are also discharged into ephemeral drainages that drain directly into the Big Horn River. Coal Draw received a total of 0.63 mgd or 0.97 cfs. Sand Draw receives a total of 0.04 mgd or 0.06 cfs.

There are no water quality data available from these ephemeral streams.

Because of the lack of any permanent streamflow and the poor quality of water associated with ephemeral streams similar to these, oil field discharge into these drainages does not have a significant impact upon them. Coal Draw is the only drainage receiving adequate discharge to sustain streamflow to its mouth — the Big Horn River. Although the treater water does not significantly affect Coal Draw, it does impact the Big Horn River.

All treater water discharged into drainages of the area alters the water quality of the Big Horn River. The DEQ analyzed the effects of all oil field waters which discharge into drainages of the Big Horn River in a letter to the Worland Board of Public Utilities dated July 10, 1974.

Their findings are as follows:

> 1. Assuming all treater water discharge between Boysen Dam and Worland reached the Big Horn River, the total dissolved solids (TDS) concentration of the river would be raised 6.8 percent (29.6 mg/l) and the sulfate (SO_4) content would be raised 3.7 percent (7.4 mg/l) on a yearly average.[1]
>
> 2. During the period that the city is using the Worland intake, 35 percent (44.4 mg/l) of the total rise in TDS which occurs between Boysen Dam and Worland may[1] be attributed to treater discharges; 25 percent (16.2 mg/l) of the total rise in sulfates may be attributed to treater discharges.
>
> 3. During the period that the city is using the Big Horn Canal intake, 16 percent (22.0 mg/l) of the total rise in TDS which occurs between Boysen Dam and Worland may[1] be attributed to treater discharges; 10 percent (7.3 mg/l) of the total rise in sulfates may be attributed to treater discharges.

The letter further stated:

> From this information, we feel confident that oil treaters are not the major cause of salt and/or sulfate loading in the Big Horn River. Setting numerical standards on salinity in streams would require us to attempt to control all salt sources, and in the Big Horn Basin this would certainly have to include irrigation return flows. At present, we do not feel that the salt and/or sulfate problem in the Big Horn River is of sufficient seriousness to warrant taking that step.

The water quality situation, however, does have an impact on the water users of Worland. Some residents of Worland import their drinking water from Ten Sleep or Thermopolis. Worland drinking water has had a laxative effect on children, new residents, and travelers who are unaccustomed to high sulfates. Water softeners and purifiers are owned by some local residents. The mineral content of the water is responsible for accelerated deterioration of plumbing fixtures and water pipes which ultimately require replacement.

One local industry is known to have installed its own water treatment facilities to improve water quality.

Basin's municipal supply is also from the Big Horn River. Water quality at Basin is somewhat less than that at Worland. Impacts to the residents of Basin are similar to the impacts on the residents of Worland.

The DEQ recognizes the fact that treater water discharge alone is not responsible for the deteriorated water quality at Worland. Nevertheless, treater water discharges do degrade the surface water downstream from Boysen Dam.

[1]This is the worst possible condition. It is debatable whether or not all the salts released by the treaters get to the river.

Associated with the deterioration of surface water quality in Cottonwood and Gooseberry Creeks and the Big Horn River is a deterioration in ground water quality. Certain stretches of Cottonwood and Gooseberry Creeks lose water to the valley alluviums and subsurface strata. Over a period of time, surface water — the quality of which has been deteriorated by treater water — will infiltrate into the ground. Eventually the quality of the near surface ground water will deteriorate. It is impossible to predict when or to what extent this will take place. Any water well drilled into the alluvium might be affected. The impact on the quality of water in the Big Horn River valley alluvium is probably insignificant.

Water discharge in ephemeral drainages is affected similarly to that of Cottonwood and Gooseberry Creeks. Much of the discharge into ephemeral drainages infiltrates into the subsurface strata. It is not known exactly to what degree the discharge water affects the quality of the near surface ground water. However, the discharge water would deteriorate the near surface ground water quality.

The above analysis considered the impacts on water quality from existing treater discharge. Future oil field discharge is difficult to predict. It is felt that existing oil fields will continue to discharge about the same amount of water for the next five years. The impacts already identified would therefore continue. The discovery of a new oil field in the Grass Creek area is possible. The impacts from treater water discharge would depend upon what drainage received the discharge water.

The second major impact associated with oil field water discharge is the increase in the streamflow. It is estimated that the treater water discharge supplies five percent of the annual runoff from the Grass Creek area to the Big Horn River. On an annual basis, five percent is not of significant importance. During the irrigation season, however, oil fields supply enough water to have a significant effect on the water supply.

The most pronounced impact is on Cottonwood Creek. On an annual basis, about one-third of the streamflow (1941 to 1945) comes from oil fields. During the summer, over one-half of the streamflow may be attributed to oil field discharge. The increased streamflow during the summer is important for agriculture. The discharged oil field waters into Cottonwood Creek are adequate to irrigate 868 acres.[1] This could provide 1,519 tons of hay per year worth a total of $83,545.[2]

On Gooseberry Creek the oil field discharge water is adequate to irrigate an additional 51 acres. This could provide 89 tons of hay per year worth a total of $4,908.

None of the produced water that is discharged into ephemeral streams draining directly into the Big Horn River is known to be used for agricultural purposes.

The above analysis on discharge water concerned itself with the impact from present discharge. Should discharge increase, the potential for more irrigation would also increase, assuming there are suitable lands for irrigation. The opposite would also be true.

[1]Based on the State Engineer's policy of adjudicating 1 cfs per 70 irrigable acres and assuming all discharge water is used for irrigation.

[2]Assuming 1.75 tons of hay per acre valued at $55 per ton.

Other Impacts Other less severe impacts which affect the water resource may result during the production phase.

Discharge pits — those pits which hold the treater water prior to discharge into a drainage — were observed to have large (1 to 15 barrels) quantities of oil. In some cases, this oil was not periodically skimmed off and recycled through the treater system. This oil continued to accumulate unless it is burned off.

The accumulation of oil in the pit increases the likelihood of greater concentrations of oil being discharged with the water, thus deteriorating water quality.

Reservoir failure or overflow would also have a greater impact if it contained a great amount of oil.

Observation indicated that almost no pits were lined with an impermeable substance. Leakage at the face of the pit, or through sandstone outcrops along the edges of the pits was observed. The oil fluids then flowed into nearby drainages. It is estimated the leakage of fluids far exceeded DEQ discharge limits on oil and grease concentrations.

The highly mineralized discharge water precipitates substances on the streambeds immediately downstream from each discharge point. The precipitated minerals ranged in color from black to white. Limited observation indicated that the precipitated minerals were calcareous (limestone). The precipitated minerals formed a hard, cement-like surface over the width of the stream channel and on all vegetation touched by the water. It is not known whether or not the precipitates extend to the perennial streams.

Abandonment

Oil Dumping In the abandonment phase of oil and gas leasing, all equipment is removed from the well site and the land is rehabilitated. In some cases, small quantities of oil may be indiscriminately discharged from pipes or tank batteries during this phase. It is unlikely that this oil would reach a live body of water or the groundwater table. The oil is usually covered by earthmoving equipment. The impact of such small discharges is minor unless the oil enters surface or groundwater.

Erosion and Sediment Yield During the time before vegetation can be reestablished on the well site, there is more erosion than from adjacent range or timbered land. The amount of erosion from the Grass Creek area could not be quantified.

Water Wells In some cases, the BLM or private ranchers may acquire non-productive oil wells for stockwatering or irrigation purposes. In the Grass Creek area there are four wells drilled by oil companies which were turned over to the BLM. These wells are often useful in establishing a better water distribution system for livestock.

Plants

Aquatic

Impacts on aquatic vegetation could occur as the result of these effects on water of oil and gas operations: contamination by accidental oil spill, increased water temperature from treater facilities, siltation of streams as a result of surface disturbance, and accidental release of chemicals in surface drainages. Prolonged exposure to such affected water would destroy aquatics, including the phytoplankton and algal species, as well as most vascular aquatics.

The increase in water temperatures from treaters may well have a positive impact on some aquatics. All such discharges observed seem to favor the growth of certain algae and moss.

Siltation resulting from soil surface disturbance probably has the greatest adverse impact on aquatic vegetation. The amount of such damage that can be attributed to oil and gas operations is hard to assess, since other uses of the land also contribute to this impact. Grazing, for example, is probably the biggest single cause of soil loss and siltation.

Terrestrial

The major impact on vegetation occurs as the direct destruction of plant cover by the construction of drill pads, roads, seismograph trails, drainage crossings, pipelines, and other structures. A lesser impact may also occur on off-site vegetation, that is, vegetation immediately adjacent to the disturbed site. In the case of off-site vegetation, the impacts may be in the form of competition from lesser or undesirable species that invade the disturbed area, by loss of habitat from erosion, soil compaction, siltation, or from mechanical injury by equipment.

A survey of the 25 oil fields in the study area shows approximately 2,700 acres of surface disturbance. Of this, about 1,200 acres are considered to be permanently destroyed as far as eventual production of vegetation. These sites include such things as gravelled or hard surfaced roads, buildings, tank batteries, cement pads, storage pits, and other permanent structures. Conceivably, most of the area could be reclaimed if and when the facilities are eventually abandoned.

The remaining 1,500 acres of disturbed surface are adjacent to the above sites and vary from heavy excavation to light stripping to remove brush. These sites, unless artificially revegetated, are usually in some stage of natural succession which is often a slow process. Undesirable species such as thistle, cocklebur, halogeton, cheatgrass, and rabbitbrush often occupy these areas and provide a seed

source for infesting surrounding sites. In many instances, these sites are subject to repeated disturbance by subsequent or recurring oil field activity. Eventually these may become sterile due to loss of topsoil and natural fertilizer.

An estimated 300 to 400 miles of seismograph lines are run each year in the Grass Creek study area. Vegetation damage depends on the type of activity and the terrain involved. If dozer work is held to a minimum, permanent damage is usually negligible. Plant damage by truck and equipment travel on old trails or off-road is usually minor.

Buried pipelines for transporting oil or gas from wells or fields to distribution points or refinery facilities usually result in considerable destruction or vegetation during the construction phase. A cleared line is usually necessary to accommodate the construction equipment. BLM right-of-way stipulations require reseeding after construction. However, reseeding efforts, especially in dry areas or poor soils, are not always successful. The result is a disturbed area that becomes infested with undesirable species such as Russian thistle, halogeton, and cheatgrass. If a service road is maintained on the line, the whole length of the line becomes an avenue for the spread of undesirable vegetation by seeds being carried by passing vehicles.

The possibility of damage or destruction of vegetation by toxic emissions seems to be remote. It is feasible that sulfur dioxide resulting from the flaring of hydrogen sulfide could damage some tree species; however, there is no documented evidence of this happening.

In many instances, production water that meets state environmental quality standards is being diverted by ranchers and farmers to supplement their irrigation waters. On the surface, this appears to be a beneficial aspect. However, some soil and agronomy specialists warn that this may backfire in the long run since the water can contain concentrations of salts which are higher than the natural waters and could, over a long period, cause loss of production from fields due to salt concentrations in the soil.

Wild Horses

Wild horses seem to react to different types of human activities in various ways. The horses in the Sand Draw area have adapted to the activities in the Sand Draw oil field. This is an old, established field, and human activity is limited. The horses depend on the field for water during certain seasons.

In most cases, wild horses react to new, short-term activity such as seismograph work by leaving the vicinity for the duration of the work. There have been reports of harassment of horses by seismograph crews. On occasion, oil and gas crews have reported horses trapped in mudholes and crippled animals needing attention.

Cattleguards are often installed in fences to replace gates extensively used by oil companies. These cattleguards can be a danger to wild horses or livestock should they attempt to cross them.

Horses could become trapped in open mudpits and sumps in their search for water during drought periods.

Domestic Livestock

Cattle and sheep are often found grazing in oil fields, seemingly undisturbed by the activities going on around them. Production water is often used by ranchers to supplement meager natural stockwater. It is conceivable that some water could contain toxic material that would harm livestock.

Open mudpits and sumps are a definite hazard to livestock and claim a number of animals each year. Oil field traffic is a hazard to animals on the road.

Fish and Wildlife

General Analysis

The oil and gas industry has been operating in the study area for over 60 years. The industry in all its aspects has had tremendous impacts upon the fish and wildlife resources during this time. From all indications, by far the most significant and severe impacts caused by the oil and gas industry have already been inflicted upon the fish and wildlife resources. This happened during the peak years of exploration and major field development in the study area. This analysis does not attempt to analyze these past impacts, but will consider the consequences of the present oil and gas leasing program as it affects fish and wildlife populations, given the probable extent of industry activities as projected for the near future.

As previously stated, for the purpose of this analysis we have assumed that no major new fields will be discovered. Preliminary exploration is expected to increase about five percent per year above the 345 miles of seismic lines ran in 1975. While exploratory drilling is expected to increase at a rate of about five percent per year above current levels, only three wildcat wells were drilled in the study area in 1975. All other drilling occurred in known fields. Field development is expected to continue at about the same level, and production is expected to decrease at about five percent annually as reserves are depleted. Conversely, abandonments are expected to increase at about five percent annually.

A number of operations associated with the oil and gas industry will cause direct mortality to wild animals ranging from individuals to entire populations. Actions which excavate, bury, overturn, clear or grade areas of previously undisturbed terrestrial habitat result in direct mortality to many small mammals, reptiles, amphibians, invertebrates, young birds, and eggs.

Any activities which cause dewatering of aquatic habitats or an addition of toxic substances to same will cause death to fish, aquatic invertebrates, and amphibians in certain stages of life.

Additional roads and increased vehicle travel on them increase road kills of deer, antelope, cottontails, and numerous other small mammals and birds. Also, past experience indicates that with more roadways, indiscriminate

and illegal shooting of animals and birds along those roadways will increase even though many species are protected by law.

Power requirements for development and production will require powerline construction. In certain situations "in flight" collision hazards to birds can occur, and powerlines increase the electrocution potential to large raptors.

It is estimated that about 500 acres of natural wildlife habitat will be removed, altered or replaced annually by surface disturbance activities or permanent facilities and structures of the oil and gas industry. At the same time, about 175 acres of previously disturbed, abandoned, and rehabilitated or naturally reestablished habitat is expected to be returning to near pre-disturbance wildlife producing capability. The difference between acreage of habitat removed and that being reestablished from past losses is about 325 acres net loss annually or about 3,250 acres over a ten-year period. (See Appendix 3.) Nearly all wildlife species found on these sites will be impacted to some degree by the physical changes in their habitat.

The actual field operations of exploration, drilling, field development, production, and abandonment, with all of the associated human activity involved, usually exposes wildlife to levels of intrusion previously unknown and sometimes intolerable to some species. Species which cannot tolerate such activities will abandon their habitat in such areas. If suitable habitat does not exist in nearby areas or if such habitat is already occupied to its carrying capacity, these displaced animals may eventually be lost to the population, especially if the disturbance is persistent. Table 22 shows the expected degree of this type of impact upon specific animal groups under the column headed *"Operations and Human Activity."*

Using the three major impact categories underlined in preceding paragraphs, a general analysis of the probable impacts upon a variety of animal groups was made. Table 22 is a qualitative display of this analysis. Note that overall the impacts on fish and wildlife in general are expected to be relatively low. However, certain animal groups or species will be subject to moderate or high impacts of certain types during one or more phases of the proposed action. The matrix in Table 22 indicates that most of the more severe negative impacts will occur during the development and production phases. The proposed action can be expected to affect big game, upland game birds, waterfowl, raptors, and other birds to the greatest extent. The probable impacts on particular animal groups will be discussed specifically in the following sections.

Threatened or Endangered Species

The effects of the proposed action through physical habitat change upon the black-footed ferret, northern Rocky Mountain wolf, or the peregrine falcon are expected to be slight. Considering the populations of these species are very low or even questionable, the black-footed ferret is the only one which could be affected with any degree of significance by physical habitat change. During the next ten years, as much as several thousand acres of prairie dog colonies may be destroyed. The possibility that black-footed ferrets may inhabit these colonies cannot be overlooked. The loss of prairie dog colonies could result in the loss or reduction of a small population of black-footed ferrets. Given present information, however, we cannot conclude that this in fact would happen.

Human activity and field operations extending into the previously remote areas which may harbor the ferret or wolf will have negative impacts on these animals due to their secretive habits and, in the case of the wolf, inherent conflicts with humans. Many people in the west have traditionally been taught that predators in general are "bad and should be shot," and that wolves are especially undesirable. Coyotes are currently subject to intense efforts to eliminate them. A wolf can easily be mistaken for a coyote by the layman, increasing the wolf's potential for being shot by mistake. These animals can be expected to retreat from areas of even moderate human activity. Due to the lack of basic knowledge concerning the status of these species in the study area, these negative impacts cannot presently be quantified.

Big Game

Some direct mortality of big game animals could occur due to accidental blowouts, spills, or leaks of poison gas, oil, or caustic or otherwise polluted water. Some animals could die from gas poisoning or ingestion of contaminated water or vegetation. Mortality of this type is expected to be insignificant, however, barring the occurrence of some major, serious oil or gas field accident.

Additional road building into big game ranges increases the losses of animals to vehicle-animal collisions. Losses increase as roads are upgraded allowing higher speeds and as larger trucks or more traffic is accommodated. While additional collision losses due to the proposed action will be relatively small annually, they will be somewhat cumulative and continual in occurrence. Roads have a history of being difficult to abandon once people become used to using them.

Unfortunately as expansion of exploration and other phases of oil and gas activity takes place, especially in undeveloped or remote areas, there has often been an increase in illegal killing and poaching of big game. This is partially due to an influx of itinerant workers and increases in access into remote game concentrations.

The three sources of direct mortality discussed above will result in only a small percentage loss in the harvestable supply of big game animals annually but must inevitably be reflected in a reduced hunter bag.

Physical losses of native range vegetation, i.e., big game habitat on an average of 325 acres annually, can be a major impact on big game animals. (See Appendix 3.) It is not possible to predict exactly how many animals of each big game species will be affected given the uncertainties of where the industry activity will take place and the imprecise delineation of some big game crucial ranges. An approximation of the maximum probable impacts can be made using existing information on big game populations, distribution, and concentration. (See Table 14, existing environment section and Map 7.)

As indicated in Appendix 3, an estimated 600 acres of big game habitat annually will become totally or significantly reduced in usability due to the human activity and field operations of the industry. People traveling, operating equipment, constructing, blasting, living in temporary or permanent camps, operating pumps, and other field devices, etc. will cause loss in habitat value. These impacts will be most noticeable in the development and production phases. (See Table 22.)

Estimated maximum probable big game habitat losses from physical habitat destruction and losses brought about by human activities that make habitat unusable total about 925 acres per year and about 9,250 acres over a ten-year period. Using existing important habitat acreage information and present population information (Table 14, Existing Environment), it is estimated that the above acreage losses could reasonably cause elk base herd reduction of seven elk per year or 70 head over a ten-year period. These habitat losses could also result in a base herd reduction of 36 deer per year and 360 over a ten-year period and three antelope per year and 30 over a ten-year period. Maximum losses of all species would not necessarily occur, but any combination of these could occur depending upon where the bulk of industrial activity takes place.

With the information available, it is not possible to get any reasonable, quantitative estimate of what the impacts would be on white-tailed deer, if any.

Upland Game Birds

All upland game birds will be subject to a low degree of direct mortality from oil and gas industry activities. Operation of off-road vehicles, exploration rigs, and construction equipment will destroy some nests, especially of sage grouse. Some incubating nests may be abandoned. With more roads and access developed and more people working in remote areas, increased illegal kills of the grouse species can be expected and road kills will increase. Spills or blowouts may cause toxic pollutants to be deposited in the watering sources of upland game species. This could result in some mortality also.

The major impact upon upland game birds will be from the habitat alteration accompanying development and production. (See Table 22.) Sage grouse will experience the major negative impact. Removal of the sagebrush type with the various construction activities could result in important habitat losses of up to 325 acres per year and 3,250 acres over ten years. (See Appendix 3.) Should the bulk of these activities take place in sage grouse winter concentration areas or in breeding-nesting areas, the impact will be significant. Since identified important sage grouse areas total nearly 80,000 acres, it can be seen that over four percent of this habitat could be lost over a ten-year period. (See Map 7.) The base sage grouse population could be reduced similarly.

Mourning doves, chukars, mountain grouse (blue and ruffed), Hungarian partridge, and pheasants will suffer habitat losses also, but the overall effects are expected to be less than for sage grouse. Some of the ill effects of habitat loss and destruction for chukars and doves will be offset by the positive impacts of increased weed type species expected to come into disturbed areas. These birds feed heavily on the seeds of weedy species. Habitat supporting the other game birds mentioned above is expected to make up only a small part of the upland game bird habitat loss.

All of the upland game birds may experience some benefit to the extent that oil and gas activities may directly or indirectly increase good quality surface water in arid areas. Any positive benefit depends upon the water being of good quality, dependable flow, and made available through responsible development by some individual, group, or agency.

Human activity and field operation disturbances hold the potential to further diminish upland game bird habitat by as much as 600 acres per year and 6,000 acres over ten years by rendering important or critical areas unusable. Here again, the greatest impact can be expected to fall on sage grouse and, to a lesser extent, on chukars. Sage grouse can be impacted severely where traditional winter areas and breeding-nesting complexes are infringed upon by industry activities. Up to 7.5 percent of the identified sage grouse concentration areas and at least this much of the population there could be lost due to this type of impact.

Losses of upland game birds may go as high as 12 to 13 percent of the existing population of sage grouse and lesser numbers of other species from the various types of impacts.

Waterfowl

Effects upon waterfowl will be felt primarily by ducks. During the preliminary phases of industrial activity, the impacts will be insignificant; but as field development and production proceed, direct mortality of waterfowl will increase with the number of accidental spills and leaks of oil or toxic substances into water courses, sloughs, and ponds. Evaporation pits and mudpits containing concentrated salts, oil film, and other toxic substances often trap or poison birds which land in them. Many pits recently observed in the study area are serious hazards to waterfowl.

During the development phases, some riparian or other vegetative cover near favorable aquatic habitats will be destroyed. This is often good waterfowl nesting cover. The extent of this type habitat loss is expected to be low because of presently used protective stipulations related to activities near water. Construction activities sometimes alter springs, seeps, etc. which are source water for ponds or sloughs. Leaks or spills of oil, caustic or salty water, or other toxic substances sometimes flow or seep into ponds or drainages killing aquatic and riparian vegetation and soil and aquatic organisms. Waterfowl food and cover will be lost.

An important positive effect upon ducks has been noted with the produced water from the Hamilton Dome field and to a lesser extent with some other fields. Much of the water flowing from wells in these fields meets state water quality standards and provides additional aquatic habitat for nesting and resting migratory ducks. To the extent that this situation expands, duck habitat and numbers will expand. The warm produced water tends to stay open later into the winter. Additional produced water would encourage more migrating ducks to remain in the study area later

TABLE 22

Qualitative Matrix of Anticipated Impacts on Fish and Wildlife with Continuation of Oil & Gas Leasing — Grass Creek Area[1]

	Preliminary Exploration			Exploratory Drilling			Development			Production			Abandonment		
	Direct Mortal-ity	Habitat Change	Opers. and Human Acti-vity	Direct Mortal-ity	Habitat Change	Opers. and Human Acti-vity	Direct Mortal-ity	Habitat Change	Opers. and Human Acti-vity	Direct Mortal-ity	Habitat Change	Opers. and Human Acti-vity	Direct Mortal-ity	Habitat Change	Opers. and Human Acti-vity
Threatened or End. Species	—[2]	Low Neg	Mod Neg	—	Low Neg	Low Neg	—	Low Neg	Mod Neg	—	Low Neg	High Neg	—	—	Low Neg
Big Game	Low	Mod Neg	Low Neg	—	Mod Neg	Mod Neg	Low	High Neg	High Neg	Low	Mod Neg	High Neg	—	—	Low Neg
Upland Game Birds	Low	Low Neg	Low Neg	Low	Low Neg	Low Neg	Low	Mod Neg	Mod Neg	Low	Mod Neg	Mod Neg	—	—	Low Neg
Waterfowl	—[2]	—	—	—	—	—	Mod	Low Neg	Low Neg	Mod	Mod Pos	Mod Neg	—	High Neg	—
Raptors & Other Birds	Low	Low Neg	Low Neg	Low	Low Neg	Low Neg	Mod	Mod Neg	Low Neg	Mod	Mod Neg	Low Neg	—	—	Low Neg
Predator & Furbearers	Low	—	—	—	Low Neg	Low Neg	Low	Low Neg	High Neg	Mod	Low Neg	High Neg	—		
Small Mammals	Low	Low Neg	—	Mod	Mod Neg	—	Mod	Mod Neg	—	Mod	Low Neg	—	Low	Low Neg	—
Reptiles & Amphibians	—[2]	—	—	Low	—	—	Low	Low Neg	—	Low	Low Pos	—	Low	Low Neg	—
Invertebrates	—[2]	—	—	—	Low Neg	—	—	Mod Neg	—	—	Low Neg	—	—	—	—
Fish	—[2]	Low Neg	—	—	Low Neg	—	—	Mod Neg	—	Low	Low Neg	—	—	Mod Neg	—

[1]Compiled by district staff
[2]Indicates insignificant or negligible impact

into the winter. As the abandonment phase of oil and gas activities proceeds in fields supporting duck habitat with produced water, a negative impact would be felt by ducks if these waters are reinjected or cut off. Should this happen, the extent of losses cannot presently be quantified; but losses in duck habitat would be significant.

Human activity and field operations in and near riparian habitat will discourage duck and goose nesting activity. Certain areas along the Big Horn River, Greybull River, and other major streams could be seriously affected should extensive production occur there.

Raptors and Other Birds

The nests and newly hatched young of ground and shrub nesting birds will suffer direct mortality from exploration, drilling, and field development during nesting periods. New roads with more travel will increase road kills of many small birds and raptors which feed on road-killed animals. Powerlines not constructed to certain specifications may electrocute raptors and other large birds.

Shore birds are subject to mortality from spills, leaks, or blowouts involving oil or other toxic substances. During industry activity phases involving influx of workers and increased access into new areas, an increase in illegal shooting of raptors can be expected.

The several hundred acres subject to removal of native vegetation annually will result in lost habitat for the variety of birds dependent upon the particular habitat removed. The species affected will depend upon the type of habitat removed. Small birds such as Brewer's sparrow and the sage thrasher may decline locally if suitable unoccupied alternate habitat is not available. Some species dependent upon weed seeds for food may benefit from the weeds coming into disturbed areas. Where vegetation is destroyed by spills or leaks of toxic substances, bird habitat may also be destroyed.

All raptors, particularly eagles, prairie falcons, and ferruginous hawks, are intolerant of human activities in nesting areas. Nests will be disrupted and abandoned in some areas, but the incidence is expected to be low due to the wide dispersal of raptors over the study area.

Predators and Furbearers

Industry-caused direct mortality of predators and furbearers will be generally low. Some losses attributable to increased road kill and indiscriminate shooting will be evident, especially among such species as fox, skunk, and badger. Mink, muskrat, and beaver could suffer losses due to spills or leaks of oil or toxic substances into aquatic habitats utilized by them.

Destruction of vegetation and habitat supporting small mammals or other prey species will reduce food sources for predators or furbearers dependent upon them. If unutilized or alternate prey sources are not available in nearby areas, populations of the predatory species will eventually be reduced. Considering the acreage of annual habitat loss projected for the study area (350 acres) and the relatively sparse population density of most predatory mammals, it appears losses from physical habitat changes will be small. Beaver, muskrat, mink, and racoon may suffer more serious losses should industrial activities destroy significant acreages of riparian habitat.

The larger predators — mountain lion, black bear, coyote, bobcat, fox, and possibly lynx and the endangered Rocky Mountain grey wolf — will be affected more severely from concentrations of human activity and field operations than from other types of impact. These animals are secretive, wide ranging, and conditioned through years of conflict with humans to avoid contact with them and their contraptions. These animals will simply move out when conditions go beyond their tolerance levels. When this occurs, other habitat capable of absorbing their numbers must be found or over a period of time their numbers will decline to a level that the remaining suitable area will support. Again, the impacts on the variety of species involved here cannot be quantified with existing information.

Small Mammals

Cottontail rabbits, ground squirrels, prairie dogs, chipmunks, and other small rodents will be destroyed in some areas where earthmoving and construction work excavates, crushes, or buries them. This impact will be most severe during the drilling and development phases. (See Table 22.) Prairie dog towns could be destroyed or severely depleted in many areas. Animals such as cottontails and ground squirrels will be destroyed in increasing numbers by vehicle travel as road building and travel increases in production areas.

The loss of 325 acres of natural vegetation annually will result in severe reductions in most native small mammal populations on these sites. Impacts can be more severe where riparian habitat or timbered sites are destroyed.

While it is not possible to quantify impacts on small mammals in numbers of animals lost, native small mammal populations will be severely reduced on an estimated 3,000 to 6,000 acre area over a ten-year period due to increased animal and habitat destruction.

Reptiles and Amphibians

Drilling, construction, and development activities will destroy present populations of eastern short-horned lizards, sagebrush lizards, most prairie rattlesnakes, bullsnakes, and wandering garter snakes on the sites where these activities occur. Accidental spills and leaks of oil or toxic substances may destroy animals such as turtles, frogs, toads, and salamanders where these substances get into drainages, low moist areas, seeps, ponds, or streams. Habitat polluted with toxic substances may be rendered useless for many years.

Amphibians and turtles may benefit significantly from free-flowing produced water if it is of high enough quality. Conversely, if during the abandonment stage the existing produced water flows supporting amphibian life are cut off or reinjected, existing populations dependent upon them will be lost.

Invertebrates

Existing insect populations are diverse, numerous, and important for their positions in food chains. Loss of vegetation through drilling, construction, and development activities will result in destruction of the insect and other invertebrate populations. Environmental damage from industrial activities followed by reclamation attempts or invasion of early succession "weedy" vegetation will result in reduced invertebrate population and changed species compositions. The role of different species which may establish in a disturbed area may be favorable in some insect-plant or insect-other animal interactions or undesirable as a result of one or more species becoming pests on desired vegetation.

Such aquatic invertebrates such as snails and crustaceans which provide food for various fishes and other aquatic animals, may be destroyed or depleted by spills or leaks of oil and toxic substances into drainages or waters. Some produced water, while meeting state quality standards, may contain concentrations of some substances which will destroy or prevent reproduction of some species of invertebrates. Information is presently lacking with which to analyze such impacts adequately.

Fisheries

Direct mortality of fishes is expected to be insignificant barring serious accidental discharge of toxic substances which reach fish habitat.

Produced water entering streams may negatively impact fisheries by creating temperature conditions which some species cannot tolerate or by reducing aquatic insect populations through water pollution. Impacts may take the form of changed fish species composition in certain streams or sections of streams or in reduced populations due to reduced food sources. In some streams, produced water can encourage lavish growth of sedges and rushes to the point that channels are choked with vegetation and organic litter. This situation seems to preclude or reduce game fish production. A much more thorough analysis of the effects of produced water in particular streams must be accomplished before an adequate analysis of this type of impact upon fisheries can be made.

Produced water from the Hamilton Dome field is providing significant flow into the Cottonwood Creek drainage. Fish populations do exist in the creek below the produced water inflow though it is primarily non-game fishery habitat. Should abandonment activities cut off these flows, it is probable that the stream would dry up in some sections during some years. This would eliminate present fish populations in these areas.

Surface disturbances resulting in increased erosion and sediment runoff reaching fisheries habitat may do significant damage locally to spawning beds and cause loss of aquatic insect producing areas. This will reduce the fish-producing capabilities of the streams affected. This could be a serious problem in some areas of steep terrain, fragile soils, and high quality fisheries such as on the upper South Fork of Owl Creek.

Ecological Interrelationships

Succession

Direct effects on flora would be crushing and removing of existing plant species at the project sites. Impacts on flora would be a change toward lower stages of plant succession. A change in soil and soil micro-organisms would result in reduced ability to inhabit the compacted and more arid soil. In general, the impacts would be a replacement of mature plant and animal communities with lower successional stages of plants and associated fauna. The sagebrush-saltbush communities within the study area provide food and cover for wildlife game species. Many of these are dependent, at least in part, upon a vegetative community in a subclimax condition. In this area, the disturbance effect of the oil and gas actions would benefit these animal species. Under normal plant succession, it would be expected that eventually this advantage would be lost as plant succession progressed. In the sagebrush communities, the time of succession would be much shorter than in the other community areas.

In forested areas plant succession would take 50 to 100 years to reach its present status. Plant succession in unprotected (from livestock) sagebrush types might reach its present status in 20 to 30 years.

Riparian communities will be impacted adversely where channels are crossed by equipment and water quality is seriously degraded by discharge of treater water.

Food and Community Relationships

The greatest impact would be the alteration of the plant communities and the corresponding adverse influence on the animal communities.

The combined effects of topsoil loss and partial or complete removal of vegetation would have an adverse impact on the productivity of vegetation. A reduction in the total amount of vegetation produced would impact in a magnified way all animals that either feed on vegetation (herbivores) or animals that prey on the herbivores (carnivores). Removing or impairing the productivity of vegetation has severe impacts reflected in all animal life subsisting on the productivity of the vegetative cover. Exposure of soil through removal or destruction of vegetative cover would increase soil temperature and drying and adversely affect interrelationships of bacteria and micro-organisms in the soil. This change would likely slow down nutrient cycles in the soil and affect productivity.

Removal or disturbance of existing vegetation and replacement by a lower successional stage might increase populations of some prey species (such as rodents) utilized by large raptors and mammalian predators. If this were to occur, the impacts would be impossible to assess without determining factors presently limiting raptor and predator populations.

During the development phase, daily and seasonal movements of animals might be blocked or interrupted. The more mobile species would probably not suffer appre-

ciably, but smaller animals with small home ranges would be adversely affected. Some animals may die if blocked from important parts of their habitat.

Primary impacts of the proposed actions on small non-game mammals, birds, and reptiles would be: (1) outright killing of some individuals by construction and maintenance activities (mainly species unable to move quickly because of stages in their life cycle, or other factors, i.e., a snake or lizard sunning itself on a cold morning); (2) alteration of habitat by removal or reduction of existing vegetation with subsequent increase of secondary successional vegetation depriving some species of essential food and cover. Other primary impacts would involve physical destruction of dens and nests located in the soil or vegetation.

Secondary impacts would include those resulting from increased human activity made possible because of new access. These would include increased legal and illegal hunting and disturbance and harassment of wildlife. Effects of construction could be the blocking of washes or intermittent streams; removal of vegetation; increased surface erosion; reduction in soil moisture levels; crushing of animal dens, shelters, cavities, and nests. The impacts would be death for animals and their progeny, alteration of their habitat through reduced food and cover, and displacement from their home range.

Major effects on deer and antelope would be the removal of existing vegetation and the increase of secondary successional vegetation. In some cases, secondary successional vegetation is preferred by mule deer and antelope, and wildlife species would probably increase their use in these areas. This increase cannot be predicted from available data. Earlier successional stages would create an "edge effect" that would benefit these two species.

Landscape Character, Recreation

Impacts from the oil and gas industry in the Grass Creek region affect recreationists and the landscape both intensively and extensively. Intensive impacts are those that stem from concentrated use areas such as a producing field or a related power transmission area. Extensive impacts are those which affect a diverse amount of land such as is covered in preliminary exploration. Each of these categories can be delineated as follows.

Intensive Impacts

Landscape Intensive impacts are derived mainly from two of the five phases of oil and gas production. These two phases are development drilling and the actual production of the petroleum.

Development drilling may occur over a wide area; its visual impact is usually severe immediately surrounding the well due to the number of facilities constructed and the proximity of wells. Within a known geologic structure (KGS) the landscape is usually industrial in character in the foreground. Thus for the 24 producing fields in the analysis area, there is a foreground and middleground zone in which development drilling will change the extent but not character of the impact area. These zones are illustrated on Map 9 and reflect the limits placed by topography and visual proximity to these fields.

A developmental well outside a KGS usually implies the subsequent creation of a producing well or field. In this case, the regular spacing of the leased areas imposes a regular drilling pattern on an irregular land form. Especially in mountainous-badlands topography, the presence of regularly spaced wells, storage tanks, or pipelines will contrast with the surrounding land forms.

Development wells usually require a drill pad and service area; forested lands, ridgetops, high relief slopes, and inhabited locations are highly visible and sensitive to public scrutiny. (Often the access roads may exceed the drill pad in terms of visual intrusiveness.) A well spacing of 40 acres results in 16 wells per section and the development of an average of four miles of access road. The ridgetops at the study area's western fringe, especially south of Sugarloaf Mountain, near Soapy Dale and Leon Baird Peaks, and south of the Wood River, are highly susceptible to visual impact. This can be attributed to their present undeveloped state, conspicuous relief, forested and watered character, and harmonious appearance.

When the production facilities are installed, the landscape has usually been radically altered. Preliminary exploration, exploratory, and development drilling have resulted in access roads, levelled drill pads, off-road trails, and tank facilities. Thus, production facilities usually aggravate an existing intrusion. Single-colored storage tanks, pumps, above- or below-ground lines, and power distribution facilities will draw attention to the disturbed area. The associated noise, odor, and clamor may radically alter a formerly pastoral and primitive landscape.

At present, production facilities grace all the known oil bearing geological structures in the study area. For the badlands east of the Absaroka Mountain range, these facilities act as focal points in the landscape. Although incongruous, they offer relief to a muted and often "uninteresting" panorama and may actually add interest to the casual visitor's experience. Exceptions would be the East Ridge-Wild Horse Heaven area, the Red Butte area, and the north face of Tatman Mountain. Here the banded clays and relief add interest, and visual disturbance would detract from rather than enhance the visitor's experience.

For the mountainous areas, the presence of running streams, forested slopes and flowered valleys, abundance of animal life, and general topography present an engaging appearance. Alterations for the most part will be perceived as degradations of the area's character and a loss of scenic value.

Recreation The criteria which determines the degree of impact include how much previous disturbance has occurred and the total importance of the values impacted.

Existing oil fields have already altered the recreation experience. Since these fields often coincide with the rimmed basins paralleling the Absaroka Mountains, they also coincide with the larger deer, antelope, and upland bird areas in the Grass Creek Unit. For the most part, these fields have had a beneficial impact on recreationists. The undeveloped quality of the area is still largely intact. Yet, the access roads have provided corridors of use and enhanced

the shooting opportunities and safety of the general hunting public. Within the oil fields themselves there are hazards present (noxious fumes, heavy equipment, potentially explosive chemicals). However, overall hunting safety and opportunity have been improved through the field operations.

The development of new intensive use areas can have much more adverse impact on recreation values in the unit. Since this use implies vastly upgraded transportation systems and permanent facility construction, all high-value primitive areas identified in BLM land-use plans for the area would be badly disturbed by this activity. It is likely that new access would be followed by subsequent, radiating off-road-vehicle use. Thus the intensively disturbed area might end up much larger than the originally impacted lands.

New intensive use areas will also impact such scattered uses as hunting, hiking, camping, and sightseeing. Benefits can include improved and safer access, acquired legal access, increased signing, and increased streamflows through discharge water. Conversely, recreationists may be adversely affected if the new use area disturbs critical wildlife habitat, allows too much access into fragile soil areas or communities, reduces area of roadless lands, increases danger from field operations, and generates possible future oil spills into fishing waters. The possibility of benefits or adverse impacts is entirely dependent on the location of new intensive use areas.

Extensive Impacts

The major recreation resources in the area are not site oriented. Rather, they occur on a large scale or encompass units with certain unique qualities. The Recreation Information System (RIS) inventory has been completed for 75 percent of the affected lands. Values on a descending A, B, C scale were assigned to the inventoried lands for different recreational activities. Included were: hunting (elk, deer, antelope, upland game, waterfowl, small game), fishing swimming-water sports, winter sports, off-road-vehicle use, rock collecting, primitive values, floatboating, sightseeing (general, botanical, zoological, historical, and geological), and itemized special interests. Lands which receive a C or B rating had few distinguishing characteristics as opposed to the overall area. Values were present at only moderate levels. Therefore, the oil and gas activities would primarily affect those lands which received A quality ratings for one or several uses. The following discussion delineates these impacts.

Legend Rock Petroglyph Site has been nominated and accepted on the National Register of Historic Places. The site is located primarily on private lands in T. 44 N., R. 98 W., section 10. Edges of the site and the bluff above the cliff are public lands. Drilling within a few hundred yards of the cliff may result in disturbance of the sandstone face and will leave a visual scar within any future interpretive zone. Development of a producing well would result in long-term visual disturbance, impinge on interpretive efforts by creating odors from wells and greatly increase the likelihood of damage to the site from oil spills and associated operations.

The Gooseberry Badlands form an extensive region of eroded hills and gullies. Along Highway 433 certain sections are spectacular in terms of color, mass, lack of disturbance, and exposed relief. In T. 47 N., R. 97 W., sections 10NW¼, 11, 12, 13, 14, 15, 22, 23, 24, 25, 26, and 27, the presence of heavy machinery may seriously impair the natural appearance present. This area is relatively roadless and exploratory activities would impose straight-line compaction areas which would likely be followed by subsequent ORV enthusiasts. Although much of the Big Horn Basin is badlands, the Gooseberry region has received less disturbance than the other badland areas. Therefore, production in this area would mean the loss of a potential primitive or landmark area of several thousand acres.

A second area which presently exhibits little disturbance is the badlands from the middle fork of Fifteenmile Creek to the north. The Timber Creek-Paradise Alley area has a few seismic lines or old reservoir roads. Extensive exploration or production could completely alter the almost oppressive silence and solitude of this area. Conversely, road access would greatly enhance public accessibility and open up the area to four-wheel drive and motorcycle enthusiasts. Such a course would sacrifice one recreational value to the benefit of another. The lands could be described as T. 48 N., R. 96 W., sections 31 and 32; T. 48 N., R. 97 W., sections 2, 3, 4, 8, 9, 10, 14, 15, 16, 17, 18E½, 21, 22, 23, 24, 25, 26, 27, 28, 34, 35, and 36.

Hillberry Rim and the lands to the northwest are a third roadless area with little evidence of disturbance. The lands in T. 48 N., R. 98 W., sections 3, 4, 9, and 10 are a small pocket of eroded formations which will show disturbance at a great distance. Exploration or drilling in this area will once again result in long-term losses of primitive or scenic values.

The upper forested area near Sugarloaf Mountain will be highly susceptible to visual disturbance. An area of approximately 700 acres in T. 44 N., R. 101 W., (sections 3W½, 4, 9, 10, 19) is relatively undisturbed. If roads go against terrain contours, major slumping, and subsequent scars will result. Logging operations in nearby drainages have already slumped since roads were constructed in the 1950s. The area also has potential for development and unplanned development may radically alter this potential.

Castle Rocks and the surrounding valleys and ridges exhibit some of the sharpest relief, heaviest timber, and greatest potential for back country management in the Big Horn Basin. Lands here described include T. 44 N., R. 101 W., sections 20, 21, 28N½, and 30; T. 44 N., R. 102 W., sections 25, 26, 27, 35W½, 29W½, and 30; T. 44 N., R. 102 W., sections 25, 26, 27, 35W½, and 36. The area's beauty would be seriously marred by almost any construction activity but especially from development drilling pads and access roads. Present use is negligible. However, use of the adjacent Washakie Wilderness could easily double over the next two decades and some use may divert to adjacent public lands.

The north fork of Owl Creek is heavily forested on the north facing slopes and nearly devoid of vehicular access. Development or exploration activities will be highly visible due to the steep slopes involved and view from ridgetop to ridgetop. Present use levels are negligible but future back

country use can be expected to increase as the Bureau or local governments acquire access in prime recreation areas. Lands involved include T. 44 N., R. 102 W., sections 22, 23, and 24.

An alpine zone at about 1,000 feet on the upper tributaries of Owl Creek is highly susceptible to lasting scars due to shallow soils, serious erosion potential, and high visibility from the Washakie Wilderness Area. The area has potential for roadless designation and trail development. Any road construction or drill pad scars will mar these values and preclude future designation. The upper portions of the north, middle, and south forks of Owl Creek are included and described as: T. 44 N., R. 102 W., sections 19, 20, 21, 28, 29, 30, 32, 33, and 34; T. 43 N., R. 102 W., sections 2, 3, 4, 5, 8, 9, 10, and 11.

The middle portion of the south fork of Owl Creek, extending from Anchor Reservoir west along the reservation boundary, is nearly impassable to any sort of traffic. Due to the incised nature of the canyon, no evidence of modern man's presence is left anywhere along the canyon walls. Any activity will result in loss of wilderness values and drastically change use patterns in the area. This may actually benefit back country users by developing access. The access, however, may eventually erode the area's attraction. Lands affected include T. 43 N., R. 102 W., sections 26½, 35; T. 43 N., R. 100 W., sections 28W½, 29SE¼, 30SW¼, 31, 32; T. 42 N., R. 102 W., section 1; T. 42 N., R. 101 W., sections 1, 2S½, 3, 4, 5S½, 6, 8, 9, 10, 11; T. 42 N., R. 100 W., lot undescribed.

Upper Gooseberry Creek presently has several scattered parcels under federal management. The area has been blocked from access by Antler's Ranch and has retained a natural meadow and forest appearance. Portions have potential for recreational site or subdevelopment. Oil field activities or unregulated exploration will alter the area's appearance and may affect future use options. Lands include T. 46 N., R. 92 W., sections 13SE½, 24, 25, 36; T. 46 N., R. 91 W., sections 19 and 30.

Past oil field operations have generated extensive amounts of litter and debris. It can be expected that some additional discarding of equipment or waste product and residual surface alterations will occur, resulting in continued visual intrusions and safety hazards.

Cultural Resources

Any surface-disturbing activity generated by the proposed action has the possibility of creating an impact on cultural values. Archaeological, historical, and paleontological sites could be impacted by access provided by oil and gas activities. Access into a previously inaccessible area can create an impact which could increase exponentially with not only improvement of access but also according to sensitivity and rarity of sites.

The following activities are among those which could create impacts on cultural values.

Geophysical exploration Surface disturbance from ORV travel could cause direct damage to archaeological, historical, and paleontological features. The presence of man can lead to increased illegal artifact and fossil collection, increased damage to historical trails (by ORV use), and further loss of some historic structures or ruins.

Access roads Blading to construct roads might result in accidental loss of cultural values. Again, additional roads will allow greater access to now remote areas and may result in increased illegal artifact collecting activities.

Drill pad construction Drill pad preparation, a surface-disturbing activity, can result in the loss of cultural values.

Pipelines and powerlines These are also surface-disturbing activities. Any increased activities by man will result in further problems in protecting cultural values.

Local Economy

The benefits that accrue to the local community from oil and gas development will continue. Benefits to the private sector include income directly from oil and gas activities, as well as income from activities that provide services to oil and gas workers. These benefits include medical, retail, and home building services.

It is difficult to ascertain the number of service jobs generated by each job in oil and gas. Estimates by the State Planning Coordinator's Office indicate that 0.7 jobs are created by each job in oil and gas in the Grass Creek Planning Unit. This ratio or multiplier when applied to the number of persons employed in oil and gas provides a rough index of the total dependency of a community on oil and gas.

Table 23 indicates the dependence of other respective counties in the Big Horn Basin on oil and gas employment if the 0.7 multiplier is used. Though Park County has 12.4 percent of its labor force or approximately 940 people directly and indirectly dependent on oil and gas activities, it is estimated that only a third of these workers are employed in the Grass Creek Planning Unit.

The same is true of oil and gas employment in Big Horn County where it is estimated that less than a third of mining employment is in the Grass Creek Planning Unit. This means that about 160 people or 4 percent of the total work force of Big Horn County is directly or indirectly related to oil and gas activities in the planning unit.

In Washakie County only about 215 people or about 6 percent of the working force is employed directly and indirectly in oil and gas activities, but only about half in the study area.

Only Hot Springs County appears to be heavily committed to oil and gas activities in the study area. It is estimated that 315 people or 15 percent of the total employment is directly or indirectly related to mining and most of this is in the Grass Creek area.

The public sector of the economy benefits from oil and gas royalties, but the exact amount coming from the Grass Creek Planning Unit is difficult to determine. Complicating factors include a variable price on oil and gas and a variable rate on royalties for oil. The price on crude oil is $5.25 per barrel for "old oil" which by definition is oil produced from wells opened before 1973. Although one

TABLE 23
Work Force Dependent on Oil and Gas Development

County	Column 1 Avg. Tot. Civilian Labor Force 1970[1]	Column 2 Ann. Avg. % Civilian Work Force Employed in Mining 1972[2]	Column 3 Persons Employed in Mining (Col. 1 x Col. 2)	Column 4 % of Tot. Labor Force Dependent on Oil & Gas (Col. 2 x 0.7)	Column 5 Persons Whose Employment is Dependent on Oil & Gas	Column 6 % of Civilian Work Force Dependent on Mining (Col. 5 divided by Col. 1)
Big Horn	4,480	6.38	286	200	485	10.8
Hot Springs	2,030	9.09	185	130	315	15.5
Park	7,570	7.31	553	387	940	12.4
Washakie	3,570	3.50	125	88	215	6.0

[1]Table 18, Distribution of the Wyoming Labor Force by County, Wyoming Data Book, 1972, University of Wyoming.
[2]Wyoming Socio-Economic Data for 1972 and Change Measures 1970-1972, Center for Social Research and Development, University of Denver.

field was opened in 1974, its production was insignificant as compared to that of the entire study area. Because of this, the "old oil" price will be used for determining royalties. The royalty on oil is 12.5 percent to 25 percent of the $5.25 price per barrel, depending on the quantity of production and royalty schedule used. Generally, the high royalty rates are assessed on very productive wells. Based on this information, most wells would be assessed the 12.5 percent royalty although several may yield enough to warrant a royalty of at least 15 percent. Some 12.3 million barrels of oil were produced in the area in 1974 at approximately $5.25 a barrel, for a total value of about $65 million. It is estimated that the royalties on all oil production were assessed at an average rate higher than 12.5 percent and lower than 14 percent, meaning that between $8 and $9 million in oil royalties were generated in 1974. Counties receive 1.1 percent of the mineral royalties originating from federal lands within their corporate boundaries, meaning that between $89,000 and $100,000 accured to county revenues as a result of oil production.

Hot Springs County received 93 percent of the oil royalties from the study area, or between $82,000 and $93,000. This is a very significant part of that county's budget. County budgets vary from year to year, but in 1967 the total revenues for Hot Springs County were $1,084,000, meaning that oil royalties could amount to almost 10 percent of that county's revenue intake. Royalties to Washakie and Big Horn Counties were negligible; only two percent of the oil production in the study area occurred within their boundaries. Park County with six percent of the area oil production would have received about $6,900, which amounts to less than one percent of its budget for 1967.

Natural gas production in the area was 12.6-million cubic feet (MCF) in 1974. Prices vary depending on the individual leases from as low as $0.30 per MCF to as high as $1 per MCF, or in certain cases even higher, meaning that the value of production in the planning unit in 1973 was worth as little at $3.7 million or as much as $12.6 million. The royalties are 12.5 percent of the value of product or between $0.5 million and $1.5 million, and the counties receive 1.1 percent of these possible totals or between $5,000 and $17,000. The range of these figures appears wide; an average of between $8,000 and $12,000 seems more reasonable. Even so, these returns are meager when compared to those from oil production or the budgets of the respective counties. Using the more restricted estimate, it could be assumed that Washakie County, which produced 81 percent of the gas in the study area, would receive from $6,500 to $10,000 of the total royalties in 1974 or less than 0.2 percent of its operating budget of $598,000 for 1967. This is a very minimal benefit for Washakie County, but it is by far the greatest received by any of the counties. Consequently, gas royalties from the study area are considered negligible to the public economies of all counties involved.

Competitive and non-competitive federal leases present another source of revenues to counties. Competitive leases yield more in annual rental fees than non-competitive leases, but the rental yield is normally much less than the amount received in royalties from producing wells.

Non-competitive leases yield $.50 per acre per year and occupy a much larger acreage in the area than do competitive leases. Though the exact acreages in non-competitive leases have not been totalled, it is estimated that almost all of the 1,191,000 acres in the study area that are in the federal mineral estate and outside known geologic structures are in the non-competitive leases. But compared to royalties from oil, revenues from these leases will provide little in monetary benefits to the constituent counties. Even if 90 percent of the acres in federal control (1,072,000 acres) were held in non-competitive leases, the federal government would receive approximately $535,000 compared to more than $8 million from oil royalties. The counties receive 1.1 percent of this amount resulting in more than $89,000 from oil royalties and less than $6,000 from leases. Moreover, these benefits would accrue evenly to the four constituent counties and would not significantly affect the revenue patterns of any of them.

Hot Springs County is the only county in the Big Horn Basin that receives significant benefits from oil and gas extraction in the area. Nine percent of its labor force is employed in mining, and most of this is involved in oil and

gas activities. These jobs support at least another six percent of the employment in the county and may account for 10 to 15 percent of the total economic output of the county. Additionally, up to 10 percent of the revenues received by Hot Springs County may be generated from royalties produced in the planning unit. Hot Springs County is and will be heavily dependent on the continued production of oil and gas.

The impacts resulting from the gradual reduction of oil and gas extraction will be insignificant to the economies of Washakie, Big Horn, and Park Counties. Their local economies are diversified; mining employment is concentrated in other parts of the Basin; and fiscal budgets receive little from oil and gas royalties or mineral leases. However, Hot Springs County could lose up to 10 percent of its fiscal budget and as much as 15 percent of its employment as a result of the decrease of oil and gas extraction in the study area.

The significant loss of revenues by Hot Springs County will result in a more limited ability to provide public services, a condition which may be offset by a smaller population and a commensurate reduction in the demand for services. But excessive expenditures in capital improvements financed by long-term bonds may leave the county with heavy costs for debt service long after the demand for the facility and the ability to pay have been significantly reduced.

The private sector can be expected to suffer as much as an eight percent reduction in the demand for its work force as a result of the reduction in oil and gas extraction. Moreover, the loss of these jobs will precipitate another reduction of employment in support functions resulting in a total reduction of up to 15 percent over a period of time. This will result in some unemployment, under-employment, and a lower wage scale in some types of employment. The severity of unemployment is dependent on a number of variables. It includes the ability and willingness of workers to relocate to take advantage of employment opportunities in other areas. Also, the ability of the community to acquire new types of base economic activities may mitigate some of the impact or nullify it completely.

Even if the above actions are taken, the costs of relocation and the straining of family ties will produce social impacts on the communities involved.

No-Leasing Alternative

Implementation of the no-leasing alternative will result in a more rapid decline in the production of oil as existing wells are depleted and no new development work is done. The impacts resulting from production would similarly decline as depleted wells are abandoned. Impacts resulting from surface disturbing activities such as seismograph trails, wildcat wells, new pipelines, and new development would not occur as was predicted for the proposed action.

The major result of implementing this alternative would be the failure to utilize the oil and gas resource which remains in the area. It is assumed that if this resource remains untapped, another resource would be utilized instead. There is no way of predicting whether this would be in the form of increased oil and gas development in another area or increased development of an entirely different energy resource such as coal, hydroelectric, nuclear, solar, or other sources. Any attempt at analyzing the impact or developing this alternate energy source would be purely speculative.

POSSIBLE MITIGATING OR ENHANCING MEASURES

Air Quality

Wyoming air quality standards were set and are enforced by the State Department of Environmental Quality under the terms of the State's Environmental Quality Act of 1973. These standards are applicable to all oil and gas activities on federal lands.

Oil and gas leases should contain a stipulation that all lessees, their agents, employees, operators, and contractors must conduct their oil and gas operations in accordance with those air quality standards and regulations.

To reduce the amount of particulates introduced into the atmosphere by construction of access roads during preliminary investigations, the following procedures could be stipulated:

—Road construction will be in accord with stipulations as to width and location.
—Numbers and sizes of vehicles allowed for investigation work may be prescribed.
—Closure and revegetation will be required of unneeded roads and sites.
—Reduce the speed of the vehicles which will use the roads.

During the exploratory drill phase, the BLM will specify the locations of all access roads and drill pad sites in order to minimize surface disturbance and accompanying airborne pollutants.

Watering or surfacing of roads and drill sites may be required if dust and resulting air pollution become a problem.

Air pollution from accidents such as fires or explosions can occur at any stage of development and once in progress there is no practical mitigation procedure available. Preventive mitigating measures include careful monitoring of production and pipeline facilities, a sound contingency plan in case of oil spills or other accidents, and an effective fire prevention and suppression plan.

The release of waste gas into the atmosphere should be confined to periods of good ventilation (strong winds associated with massive air movements). Unrecoverable oil products such as sludges in storage tanks and treaters should be burned during the middle part of the day when atmospheric conditions are most favorable for rapid dispersion of combustion products. Burning should be prohibited during atmospheric inversions. Separation of liquids will normally be conducted within a closed facility such as a building or a tank in order to trap gaseous vapors and prevent them from entering the atmosphere.

Surface disposal of liquid waste such as treater water and sludge can be prohibited. Those wastes can be reinjected into the same formation from which they came.

Upon abandonment of an oil well site or access road, the road should be closed and all disturbed areas rehabilitated by revegetation or some other acceptable method of soil stabilization.

The maintenance and use of all applicable pollution control devices on internal combustion engines can significantly mitigate this source of gaseous pollutants.

Soils

Impacts on soil are in the form of soil disturbance and compaction. Both types of impacts can obviously be mitigated by reducing the amount of disturbance and rehabilitating the disturbance that occurs as quickly as possible. Following are some of the possible mitigation measures.

Soil surveys could be completed in such detail as to identify major soil series so that various agronomic and engineering interpretations can be made. Once this is done, rehabilitation measures can be hastened by recommending types and application rates of fertilizers, based on the available moisture and soil texture, designing seed bed preparation to fit the various soil conditions, and recommending proper plant species for reseeding to take advantage of existing soil conditions.

In lieu of detailed soil surveys, a qualified soil scientist should visit each site to be rehabilitated and make appropriate recommendations.

The size of the disturbed area, as well as the potential for erosion, can be significantly reduced by limiting the disturbed areas to the gentlest slopes. Erosion hazard and the potential for successful rehabilitation will be improved by returning the disturbed area to as gentle a slope as possible before attempting rehabilitation. This is especially important where soils have a slow water intake rate.

Engineering designs for access roads should be prepared by the company and reviewed and approved by watershed management and hydrology personnel prior to construction.

By protecting ephemeral stream crossings with riprap banks, the erosional impact could be reduced.

Adverse impact from abandonment of mudpits and surface disposal of liquid and solid wastes would be mitigated by strict adherence to appropriate regulations and stipulations.

Areas that are most susceptible to developing compacted layers, and the seasons of the years that those soils are most susceptible, should be identified and surface occupancy on other than existing roads should not be allowed during those periods of the year.

Where topsoil is of sufficient quality and quantity, it should be stockpiled to be used upon abandonment for rehabilitation of the site.

Areas which are not capable of supporting vegetation prior to disturbance should not be subjected to revegetation attempts but they could be returned to as near to the original contours as possible.

Areas which have a compacted zone near the surface could be mechanically ripped to loosen the compacted zone

if ripping will not create a worse impact than already exists.

Geologic Structures

If geologic investigations suggest a likelihood of subsidence occurring due to a withdrawal of subsurface fluids, then the condition can be mitigated by injecting water as oil and gas are withdrawn.

Land Use

Oil and Gas Operations

Oil and gas lessees and seismic operators are now required to submit drilling plans and notices of intent to conduct oil and gas exploration before commencing their actions on federal lands. These plans and notices are reviewed, modified as necessary, and then approved by the U.S. Geological Survey or the Bureau of Land Management. A variety of stipulations are imposed upon the oil and gas lessee or operator, some for mitigation of anticipated adverse impacts to the lands that could result. Those stipulations are found in the standard forms in Appendix 2.

Other use authorizations on public lands such as roads, powerlines, and telephone lines which are indirectly or directly related to oil and gas operations have similar surface and environmental protection stipulations.

The Bureau should stipulate in the oil and gas lease or in the lessee's drilling and development plans that all garbage, trash, junk, oil waste products, and other refuse be disposed of in accordance with the State Department of Environmental Quality's regulations. Authorized waste disposal sites should be established within oil fields unless a municipal sanitary landfill or other authorized disposal site is within a reasonable distance from the oil field. Waste generated from all exploration and seismic operations should be returned to the closest authorized disposal site. The Bureau should require cleanup of all junk, litter, and abandoned oil field equipment resulting from oil field operations on public lands.

Ranching and Agriculture

Fence all well drilling mudpits and treater water skimmer pits to keep out livestock.

Allow no drilling of wells, road construction, or construction of oil field facilities on croplands unless no reasonable alternative locations are available.

Safety and aesthetics should be considered before oil and gas development, production, and transportation facilities are authorized in populated areas or near human dwellings.

Residential/Commercial/Industrial

Establish a forum with state, county, and local governmental agencies to keep them informed on all oil and gas energy initiatives and plans involving public lands.

Encourage county and local governments to develop comprehensive land use plans and other plans to effectively deal with impacts from oil and gas and other energy development.

Inform local government agencies of federal programs and funding and planning assistance to help them cope with problems of energy development.

Timber

Coordinate access road construction by oil and gas operations with forest and timber management needs.

Water

The mitigating measures in this section are general. More specific mitigation measures will be presented in the recommended mitigation section.

Geophysical Exploration

—Require on-the-ground examination by district personnel of all geophysical lines both before and after completion.
—Obtain mitigation recommendations from the district soils scientist, district hydrologist, and fisheries biologist on all routes prior to geophysical work.
—In areas where geophysical lines cross ephemeral stream channels with a drainage greater than one square mile, the district hydrologist, soils scientist, and fisheries biologist will examine the route and make appropriate recommendations. In all cases attempts will be made to avoid drainage crossings.
—Allow no crossing of perennial streams.
—Minimize the amount of soil disturbance during rehabilitation.
—Allow no geophysical work within 1,000 feet of the Big Horn River or other perennial streams in the planning unit. Rehabilitate all disturbed areas.
—Allow no geophysical work in areas with high erosion susceptibility.

Drilling Pads, Access Roads, and Pipelines

—Require on-the-ground examination by BLM personnel of all drilling platforms before and after completion.
—Allow platforms to be constructed only on near level, less than five percent slopes.

—Limit the size of the drilling platform to the extent of the actual size needed.
—Limit the amount of earth moving work for construction of drilling platforms.
—Clear vegetation on drill pads only to the extent absolutely necessary by running over vegetation with equipment; it often speeds re-establishment of plants.
—The design for all proposed access roads must meet the approval of the district manager.
—Stockpile all topsoil for rehabilitation.
—Allow no surface occupancy on areas with critical erosion susceptibility.
—Do not construct platforms within 300 feet of ephemeral drainages which have a drainage area greater than 10 square miles. Do not allow construction of platforms within 1,000 feet of the perennial streams in the study area.
—Require proper size culverts be installed at each drainage.
—Recommend temporary stream stability structures where access roads cross stream channels.
—All disturbed areas will be rehabilitated/revegetated to the satisfaction of the district manager.
—Avoid running pipelines up slopes without providing waterbars and cutting off outside berms.

Oil Fields — KGSs

—Require on-the-ground examination of all earth moving work by BLM.
—All proposed earthmoving work must meet the approval of the district manager.
—Allow no earth moving work within 300 feet of ephemeral stream channels with a drainage of greater than 10 square miles.
—Allow no earthmoving work within 1,000 feet of perennial stream channels.
—Require proper size culverts be installed at each drainage crossing.
—Limit earthmoving work to areas where slopes are less than 15 percent.
—Rehabilitation/revegetation must be verified and accepted by the district manager before the surface protection and lease bonds are terminated.
—Require stream stability structures along stream channels.

Mudpit Discharges

—All oil within the pits should be skimmed off prior to discharge.
—Allow no discharge of mudpit fluids on public lands.
—Discharge mudpit fluids should be at least 200 feet away from ephemeral drainages and 10 miles from perennial streams in areas specified by the district manager.
—Require a standard chemical analysis of all mudpit fluids.

Discharge of Produced Water

—Allow no discharge water on public lands.
—Require discharge pits be diked, not subject to runoff from drainages.
—Treat the produced water prior to discharge to limit the amount of pollutants which enter drainages.

Plants

Aquatic

During the exploration and development phases, roads, pipelines, and other facilities can be located to minimize the destruction of aquatic vegetation at stream crossings and to avoid disturbance to aquatic habitats of significance. This can be accomplished by stipulations in leases and notices of intent before intensive exploration begins and in leases and permits before development commences.

Erosion caused by oil and gas operations during all phases is reduced by limiting surface exploration and access construction to dry months; requiring proper road and pipeline locations, construction, drainage, seeding, mulching, water bars and surfacing; using protective dikes around mudpits, exploratory wells, storage tanks, batteries, and evaporation pits; and stabilizing disturbed soil at stream crossings, channel changes or gravel removal operations in stream channels, and steep cut banks near streams.

Loss of groundwater from shallow aquifers can be minimized by casing the wells.

Mitigation of blowouts may be accomplished by using blowout preventors, using good safety and maintenance procedures, locating drilling sites away from surface waters, constructing dikes around drilling sites, using contingency plans to cover adverse impacts from blowouts, and keeping necessary equipment on hand to clean up impacted waters as soon as possible after a blowout. Equipment to suppress fires started during blowouts, as well as from explosions or other accidents, should be readily available.

Impacts of oil in aquatic vegetation from sources other than blowouts can be minimized during exploration, development, and production by installing monitoring systems in pipelines to detect and shut down mechanical failures, e.g., line-pressure sensors and block valves (National Petroleum Council, 1971); constructing berms around storage batteries, tanks and separators; giving protective coatings and cathodic treatment to prevent corrosion of pipes; insuring that evaporation pits are of sufficient size and constructed of impervious materials; reinjecting waste oils and unseparated hydrocarbons into the production formation; and adequately capping wells during abandonment to prevent oil from escaping into subsurface and surface water supplies.

Reliable methods for collecting oil after it has entered streams have not been developed. Floating booms can be used to contain and collect some of the oil that gets into

ponds or lakes. Straw is the best material to use along shores of lakes to collect spilled oil (Montgomery and McGowan, 1971).

Terrestrial

Destruction of plants by surface disturbance can be lessened by continued use of strict stipulations restricting the use of dozers and graders in seismograph operations.

Further, the amount of vegetation destroyed by clearing operations, during all phases of oil and gas leasing, can be minimized by limiting the number and dimensions of roads, pipelines, trails, test wells, camp facilities, etc. Only those actually needed to accomplish the job should be constructed; existing facilities should be used whenever possible. Limiting the number of roads and pipelines alone could reduce the amount of vegetation destroyed by 25 to 50 percent (Montgomery and McGowan, 1971).

The long-range impacts can be mitigated by strict rehabilitation requirements, including revegetation with native species, installation of mechanical erosion control devices, and by keeping the size of the disturbed areas as small as possible. This would require the removal of the foreign material, scarification of impacted sites, and revegetation with natural or introduced species. On steep areas, some interim erosion control would also be necessary.

Vegetation kills and reduction or loss of site productivity due to contamination by oil or briny water during any or all phases of oil and gas leasing can be mitigated by:

- —Locating wells, storage facilities, etc., away from drainages.
- —Constructing dikes around all facilities that generate or store contaminants, e.g., drilling pads or well sites, mudpits, storage tanks and flowlines.
- —Using proper mud weight for drilling and blowout prevention equipment.
- —Using tanks to contain fluids which may flow from wells during drill stem tests.
- —Not discharging contaminated water or other toxic material into streams or on the ground surface.
- —Re-injecting brine into the ground rather than using evaporation pits, or using only lined evaporation pits of sufficient size to preclude leakage and overflow.
- —Developing and adhering to contingency plans for controlling blowouts, spills, leaks, etc.
- —Installing monitoring systems, including X-ray tests of valves, pumps, etc., to detect and shut down mechanical failures which could result in leaks, spills, or other accidents.
- —Casing all wells and test holes where there is a possibility that oil or brine can mix with aquifers.
- —Immediately upon abandonment, sealing wells, removing storage tanks and flow lines, and draining mudpits, sumps, etc., and disposing of material in a non-polluting manner (USDI, 1972; National Petroleum Council, 1971; Montgomery and McGowan, 1971).

Wild Horses and Domestic Livestock

Some disturbance and harassment of wild horses could possibly be mitigated by a public relations program aimed at informing oil and gas people and their contractors of the laws and penalties regarding these animals. The development and implementation of wild horse management plans will also help. Increased on-the-ground supervision and population control would help minimize some of these problems.

Production water that becomes available to livestock or wild horses could be tested for toxicity and suitability. All open mudpits should be fenced to exclude wild horses, livestock and wild animals. Cattleguards can be modified to prevent injury to animals that might encounter them.

Fish and Wildlife

Anticipated impacts to fish and wildlife can be mitigated in three general ways. They are: (1) refrain from leasing crucial habitat areas; (2) lease with no occupancy stipulation on all or part of the lease; and (3) allow no exploration, drilling, and other development activity during certain periods of the year such as winter stress periods, spring calving periods, breeding or nesting seasons, and during spring runoff in watersheds supporting critical spawning habitat.

Aerial and seismic exploration activity should be timed to avoid wildlife areas during critical times. Wellheads can be located away from important habitat areas and wells drilled on a slant to explore or tap pools located beneath them (Shell International Petroleum Co., 1966). Exploration impacts can be further reduced by joint use of one contractor to conduct aerial or seismic exploration for several companies.

During exploratory and production drilling, drilling water and mud can be kept out of wildlife water supplies by storing them in metal tanks or leakproof pits. Briny water resulting from producing wells should be re-injected into the ground. Mudpits located near waterfowl habitat should be covered to prevent waterfowl entering and becoming entrapped in them. Fences should be built around mudpits where there is danger of large animals falling into them.

Waste by-products from drilling and refining can be prevented from entering wildlife habitat with proper storage, treatment, and disposal into them.

During development and production phases, oil storage and refining facilities should be kept away from critical wildlife habitat areas. Powerlines located on or near heavily-used flyways should be placed underground. Safety devices to prevent electrocution of perching birds should be installed on power poles and crossarms. Utility poles located near busy roads should be designed to prevent raptors from perching on them.

Pipelines placed above ground should be designed to prevent interference with migratory habits of wildlife. Above ground installation of pipelines would provide

easier detection of leaks, reducing the hazard to wildlife habitat from oil spills (Shell International Petroleum Co., 1966).

Temporary construction camps and permanent field operation facilities can be located away from crucial wildlife habitat. Compliance with state and federal air and water quality and solid waste standards should prevent or minimize impacts on wildlife associated with these facilities.

Reclamation of abandoned drilling sites and producing fields should include revegetation of disturbed areas with plant and grass species beneficial to wildlife. Open pits should be filled in and revegetated as well.

Denuded streambanks should be replanted with grasses, forbs, and shrubs. Where streambeds have been scoured, structures can be installed upstream to create pools (gabions, log and board dams, or trash catchers), and spawning gravel can be placed in the streambed in the pools above the structures. Material should not be removed from stream channels unless a permit is obtained by the permittee or lessee from the appropriate state agency and a satisfactory plan to protect aquatic life and prevent siltation while removing the material has been approved. Streams should not be channeled or relocated unless it is absolutely necessary to do so. In any case, advice and concurrence from DEQ should be obtained beforehand. Road culverts should be designed and installed to allow fish passage.

Prevention of all accidents that result in oil pollution and harmful effects on aquatic wildlife is improbable, but their frequency and magnitude can be reduced by careful operation of drilling equipment and good maintenance procedures to prevent fires and explosions. Well blowouts can be reduced by the use of blowout preventors. Since it is most important from the standpoint of aquatic life to prevent oil from getting into streams or lakes, slant drilling could be required at specific sites to keep drilling operations further away from surface waters. In especially sensitive areas, secondary dikes can be constructed around the drilling site to contain oil in case of blowouts and during setting of drill cuttings. These measures can also alleviate increases in surface water temperature.

Saline water contamination of streams and other surface waters can be reduced by locating drilling sites away from surface waters, using tanks to contain any liquids that flow from the well during drill stem testing, preventing blowouts during exploration and development — using blowout preventors, good safety practices, and recommended drilling techniques and casing the wells.

Surveys and monitoring of aquatic communities should be done by experienced biologists who will be able to evaluate the significance of population changes. For example, certain common species of aquatic insects are susceptible to the effects of pollution by organic wastes, while other species are extremely tolerant. The elimination of sensitive species and the increase in the population of tolerant species may be used to indicate the presence of organic pollutants.

Ecological Interrelationships

All of the mitigation measures discussed in the various sections of this chapter will function in partially mitigating impacts upon the various ecosystems.

Landscape Character

The following are possible mitigating or enhancement measures to minimize adverse impacts.

—Preclude leasing of roadless areas or areas of high potential for soil erosion.

—Allow leasing but stipulate no surface occupancy on lands with fragile natural appearances.

—Preclude ridgetop locations in areas of high relief. Stipulate road constructions to occur in drainage bottoms when possible and preclude disturbance on upper third or top of scenic ridges.

—Require consultation with certain specialists prior to on-the-ground operations and use multi-discipline approach in conjunction with operators in formulating development proposals for high value areas.

—Create buffer zones around focal points in the landscape and preclude surface disturbance in these zones. Slant drilling, however, would be allowed.

—If development occurs in previously inaccessible areas and if continued activity seems assured, require construction of high enough quality roads to ensure public access and allow increased recreational use.

—To minimize accumulation of debris in operations area, mandate regular inspection of projects on public lands and provide for adequate rehabilitation of disturbed areas.

—If safety hazards are present to the recreation public (high speed traffic, hydrogen sulfide gas, etc.), signing, shutting down of operations, or exclusion of the public could be required.

Cultural Resources

Historical Resources

Unregulated mineral exploration could destroy historic ruins, trails, structures, and earthworks. Any carelessly conducted activity, be it of development or production that disturbs the historical surface or subsurface, threatens loss of tangible historical resources. This risk is always present regardless of conscientious pre-planning. Rugged hills and valley bottoms where historic Indian actions occurred and which largely determined the course of history would be altered.

Relocated historic structures could suffer loss. Likewise, obtrusive operation roads, structures, and other developments adjacent to historic places will temporarily lessen

their historical value to the degree that the scene and setting have been changed.

Paleontological Resources

Paleontological specimens, strata, or locales will suffer adverse impacts that cannot be completely mitigated if the ground surface or the level at which they are found is disturbed.

Much of the landscape can be rehabilitated and the adverse impacts reduced, but no amount of man-made rehabilitation can restore a disturbed site to its original form. Original natural features, once lost, are gone.

Archaeological Resources

An archaeological survey of the lands to be explored, developed, or disturbed in any manner should be conducted before the exploration phase begins. Given that this has been done and all archaeological values have been inventoried, tested, studied, evaluated, and, if needed, excavated, the only remaining mitigation would be to locate drill pads, seismograph lines, and transmission lines in such a way as to impact these values the least, and to avoid them if possible.

Archaeological sites should not be excavated on a "must" basis. Ideally, an archaeologist will have a problem to be solved or a particular area to explore in search of a certain set of information. He or she will then choose which site and in which area the work will be done, complete the survey on excavation, and publish the findings. Often an archaeologist will combine several seasons effort toward a major archaeological work leading to proving or disproving, modifying, or developing an entirely new theory in archaeology. Salvage archaeology without proper recording techniques would not be problem oriented and, therefore, not necessarily contribute to the solution of a large problem. All archaeological sites should be left undisturbed until it is determined that the excavation of that site can provide needed information.

If continued protection of these values in the immediate area of operation is not practical, then the site should be excavated. Material should be inventoried, curated, and stored for later study and interpretation.

The Antiquities Act of 1906 will protect archaeological values and will be a mitigating measure if it is vigorously enforced. Also, if the archaeological values are on the National Register of Historic Places or eligible for nomination, studies should be conducted and forwarded to the President's Advisory Council on Historic Preservation for comment.

Socio-Economics

Mitigation of the adverse impacts of the reduction of oil and gas extraction includes both actions which may be undertaken by local and state agencies, and those actions which can be initiated by the Bureau.

Non-Bureau Actions

Following are actions which would help mitigate the anticipated impacts but which are outside the scope of BLM action.

Hot Springs County, the school districts, and the State of Wyoming may try various strategies to retain a viable economy after oil and gas activities have subsided.

Two facts must be underscored at this point. First, it is unlikely that mining employment will cease completely even if all the fields in the study area stop production. Second, many people employed in oil and gas activities will move to other fields rather than accept local employment in another industry. Employment opportunities resulting from the attraction of new industries may be exploited by workers from outside Hot Springs County rather than by residents who had been employed in oil and gas. Nonetheless, these workers, after they become new residents, would continue to support both public and private community services.

Before the oil and gas employees are forced to leave the area, the county should institute a program to attract a different type industry which would employ oil and gas employees. It may be necessary to retrain personnel employed in oil and gas whose jobs may be eliminated. Ideally, the retraining program would complement the industries that are attracted to the community. Any discussion of the benefits of industrial expansion would not be complete without consideration of its potential disadvantages. Many communities have acquired new industries, thinking that they had found the panacea to their fiscal problems only to be burdened by unexpected service demands for water, streets, schools, sewage treatment facilities, and so on. Conversely, all viable desirable communities have a healthy, diversified, economic base. What is important is that new industrial expansion shows an immediate and long-term net benefit to the community after all the economic, social, and environmental benefits have been assessed.

Even if Hot Springs County attracts some desirable industries, it should not expect to completely mitigate the impacts of diminished oil and gas production. Special efforts should be made to avoid long-term bonds which may become due when the ability to pay has been greatly reduced. Where possible, service demands should be met with short-term expedients rather than long-term capital improvements. As an example, school districts could offer a summer session and a more flexible student vacation program to use the existing facilities more efficiently. Where capital improvements and the concomitant bond issues are unavoidable, they should be amortized as quickly as possible before revenues and income from the study area oil and gas have greatly diminished.

If the community opts for expansion of its economic base, the recreation and retirement industry as it occurs in Thermopolis could be a viable area for this expansion. Although the retirement industry requires higher than average investments in medical facilities that must be financed by the community, it is still a good, clean, base economic activity that brings dollars into the community with a minimum in environmental and economical disturbance. The

dry climate and scenic character of Hot Springs County as well as its close proximity to Bighorn and Shoshone National Forests and Yellowstone and Grand Teton National Parks makes it an ideal place for retirement and seasonal recreation.

The economic potential of Thermopolis and Hot Springs County could be exploited in many ways. The community could seek outside capital and expertise to develop and promote health spas and planned unit developments that capitalize on the mineralized hot springs, close proximity to the Legend Rock Petroglyphs, Fifteenmile Badlands, and the adjacent parks and forests discussed above. Bus tours could be offered to all adjacent recreation and resources, and a broader range of services could be encouraged to cater to the needs of new residents.

Actions by the BLM

There are two actions that the BLM may take to mitigate the effects of reduced oil and gas activities.

Most importantly, it can continue to inform the local communities of the projected oil and gas production so that local governments can deal intelligently with the problems of a changing economic base. If new technology extends the projected life of area oil fields, it is the responsibility of the BLM to issue new projections. It should be understood, however, that predictions are not prophecies; continually changing technology and imperfect knowledge lessen their reliability. However, any planning efforts, even when based on imperfect information, are preferable to no action at all.

The second action that may be taken by the BLM is to cooperate with local agencies in the development of Legend Rock and the badlands of Fifteenmile Creek as recreation resources. The number of jobs which would result and the impact on the economy by this action would depend entirely on the interest which developed in recreational use of these areas. Both resources should be subject to strict environmental and protective consideration and will not be developed if such action in any way threatens the integrity of the respective resources.

RECOMMENDATIONS FOR MITIGATION OR ENHANCEMENT

Air Quality

All of the possible mitigating or enhancing measures listed in the previous section should be implemented to reduce or eliminate the adverse impacts of oil and gas exploration, development, production, and abandonment on air quality within the study area. Some of these recommended measures cannot be unilaterally imposed upon all oil and gas leasing activiites — they must be implemented with reason and discretion and tailored to a specific situation, operation, or season to attain their objective — the maintenance of clean air.

Soils

The following measures are recommended for mitigation of the anticipated impacts.

Fairly detailed soil surveys should be completed for areas which have been identified as having potential for high activity; for example, an undefined known geologic structure which has a few producing wells and which is scheduled for further development. Various agronomic and engineering interpretations should be made on these surveys and stipulations prepared for rehabilitation measures.

All access roads should have a design prepared. A soil scientist, hydrologist, engineer, and other appropriate specialists should review the location and design prior to construction.

Where soil surveys are not available, a soil scientist should visit each site prior to rehabilitation activities to recommend proper action to take advantage of existing soil conditions, including the no-action option where attempts to revegetate a site which has never supported vegetation are obviously futile.

Well sites and sites for other facilities should be limited to the gentlest slopes feasible. All potential sites of over 10 percent slope should be reviewed by a soil scientist, hydrologist, and watershed specialist before construction and recommendations for mitigation of impacts made.

Where the topsoil on a well site is of sufficient quantity and quality, it should be stockpiled for later use and rehabilitation.

During periods when the subsurface soil is wet and subject to compaction, surface occupancy should be limited to existing roads only. Generally, this will include those periods of the year in the early spring when the soils are drying out and in the winter during periods of thawing.

In all cases, the size of disturbed areas should be strictly limited to the minimum necessary to accomplish the proposed action through strict enforcement of stipulations.

Ripping of compacted zones should be done wherever feasible.

Geologic Structures

If subsidence is likely, water should be injected into the formation as oil and gas are withdrawn.

Land Use

All of the possible mitigating or enhancing measures should be adopted and implemented to mitigate the impacts from oil and gas activities on other land uses within the study area. Present control authority and existing stipulations for oil and gas activities and other related activities such as powerline, pipeline, and road construction are comprehensive enough to adequately mitigate most direct adverse environmental impacts from oil and gas activities on public lands. Reasonable and proper application of those stipulations and diligent enforcement by BLM and USGS are requisite to achieve the objectives of minimum impacts on other land uses and on the environment from oil and gas activiites within the study area.

Water

Geophysical Exploration

Comprehensive regulation should ensure the following:

—Continue on-the-ground examination by district personnel of all geophysical lines both before and after completion.

—In areas where the slope is greater than 15 percent, the district soil scientist will examine the route and make appropriate recommendation prior to geophysical work.

—In areas where a geophysical line is to cross an ephemeral stream channel with a drainage greater than 10 square miles above the proposed crossing, the district hydrologist will examine the route and make appropriate recommendations. In all cases, reasonable attempts will be made to avoid drainage crossings.

—Any proposed crossing by geophysical equipment of Cottonwood Creek, Gooseberry Creek, Owl Creek, Grass Creek, Enos Creek, the Wood River, the Greybull River or any tributary of these streams containing live water must first be examined by the district hydrologist and fisheries biologist and appropriate recommendations made.

—Minimize the amount of soil disturbance during rehabilitation.

—Any geophysical work within 1,000 feet of the Big Horn River or west of Range 98 on Owl Creek, Cottonwood Creek, Grass Creek, Enos Creek, Goose-

berry Creek, and the Greybull River must first be examined by the district soil scientist and hydrologist and appropriate recommendations made.

Drilling Pads, Access Roads, and Pipelines

Regulations should ensure the following:
—Continue on-the-ground examination by BLM personnel of all drill pads before and after completion.
—Allow drilling pads only to be constructed on nearly level (less than 5 percent slope) ground whenever possible.
—Limit the size of drilling pads to the barest minimum.
—Limit the amount of earthmoving work for the construction of drilling pads.
—Clear vegetation on drill pads only to the extent absolutely necessary by running over vegetation with equipment; it often speeds re-establishment of plants.
—All proposed access roads and drill pads will be approved by the district manager.
—If valuable topsoil is present, stockpile for rehabilitation.
—Do not allow the construction of pads within 300 feet of ephemeral drainages which have a drainage area greater than 10 square miles.
—Do not allow the construction of pads within 500 feet of Cottonwood Creek, Gooseberry Creek, Owl Creek, Grass Creek, Enos Creek, the Wood River, the Greybull River, or any tributary of these streams containing live water without the approval of the district manager upon the recommendation of the district soil scientist and hydroloigst.
—Require proper size culverts with necessary energy dissipation devices (able to handle a 50-year runoff event) be installed at each drainage crossing.
—Require temporary stream stability structures where access roads cross stream channels and along steep (greater than 20 percent) cutbanks and fill slopes upon the recommendation of the district soil scientist and hydrologist.
—Avoid running pipelines upslope without providing waterbars and cutting off outside berms.
—Rehabilitation/revegetation must be verified and accepted by the district manager before the surface protection and lease bonds are terminated.

Oil Field KGSs

Regulations should provide for the following:
—Require on-the-ground examination by BLM personnel of all proposed earthmoving work.
—All proposed earthmoving work must meet the approval of the district manager.
—Allow no earthmoving work within 300 feet of ephemeral stream channels with a drainage area of greater than 10 square miles and perennial stream channels without the approval of the district manager with appropriate recommendations from the district soil scientist, hydrologist, and fisheries biologist.
—Require proper size culverts with energy dissipation devices (able to handle 50-year runoff event) be installed at each drainage crossing.
—Limit the location of earthmoving work to areas where slopes are less than 15 percent wherever possible. Appropriate recommendations will be made by the district soil scientist in areas where slopes are greater than 15 percent.
—Revegetate immediately.
—Require temporary stream stability structures along stream channels and where slopes are greater than 20 percent as recommended by the district soil scientist and hydrologist.

Mudpit Discharges

Regulations should ensure the following:
—All oil within the pit should be skimmed off prior to discharge.
—A standard chemical analysis including total dissolved solids, sulfates, carbonates, pH, chemical oxygen demand, and oil and grease should be made by a laboratory approved by the district manager prior to a request to discharge by the oil drilling company. The district manager may also require additional tests as recommended by the district hydrologist.
—Allow no discharge in any drainages defined by the district manager. All discharges should be at least 200 feet from ephemeral drainages and 10 miles from perennial streams in areas specified by the district manager with appropriate recommendation from the district hydrologist.

Discharge of Produced Water

Recommended mitigating measures are:
—BLM examines all proposals to discharge water on public lands and determines if discharge is desirable.
—Require all discharge pits be diked and not subject to runoff from drainages.

Plants

General

All the possible mitigating or enhancing measures listed in the previous sections for aquatic and terrestrial plants as well as those below are recommended for adoption to mitigate oil and gas impacts.

Aquatic

It is recommended that all field activities be monitored closely for accidental oil spills and pipeline leaks. BLM should insist upon immediate action to control this type of contamination and on adherence to environmental quality standards for discharge waters into streams. This will

require a close, cooperative effort by the BLM with the oil producers, DEQ, EPA, and USGS.

Terrestrial

The following mitigation measures are recommended:

—Continue the use of strict stipulations restricting the use of dozers and graders in seismograph operations.

—Enforce strict rehabilitation requirements including revegetation with native species, installation of mechanical erosion control devices, removal of foreign material, and scarification of sites with compacted soils.

—BLM will work closely with oil producers in restricting the size of disturbed areas to as small as possible.

Wild Horses and Domestic Livestock

All mitigation measures outlined in the possible mitigation measures section should be implemented.

Fish and Wildlife

Threatened or Endangered Species

The Bureau should initiate field studies to determine presence, population densities, and to acquire other important data concerning threatened or endangered species.

If populations are authenticated and delineated, there should be no leasing of crucial areas for black-footed ferrets and the Rocky Mountain wolf.

If a good possibility of existing black-footed ferret populations can be established, there should be no occupancy allowed on large prairie dog towns containing the ferret populations.

Big Game

There should be no leasing in crucial elk winter areas such as the south fork of Owl Creek Canyon.

Smaller critical elk winter ranges should be protected through a no-occupancy stipulation. Examples are the wind-blown grass and sage-brush slopes and ridgetops found on the upper south fork of the north fork of Owl Creek, upper north fork of Owl Creek, Castle Rocks, and upper Cottonwood Creek.

There should be no exploration, drilling, or development work from December 1 through June 30 in crucial elk or deer winter ranges or fawning areas. The Bureau should undertake studies which will enable them to better delineate these areas.

Stipulate vegetation rehabilitation in big game habitat areas to include seeding of important browse-grass-forb mixtures which will grow in the area and which will be nutritious, palatable, forage for the big game species present in the area.

In antelope range, the Bureau should permit no severe depletion or pollution of existing federally-owned or controlled surface waters (reservoirs, springs, etc.) and increase efforts within BLM, USGS, and the oil industry to locate good water-bearing strata which could be developed for wildlife use. Clarify and simplify the system by which BLM can acquire and develop high potential waters found by industry at dry hole sites. Examples of appropriate stipulations are found in WSO Forms 3045-4 and 3045-1. (See Appendix 2.)

In all big game ranges, require the use of existing roads where possible, thus minimizing new road construction. Where new roads are necessary, they should be located to avoid important browse habitat and timber cover sites. The district wildlife biologist will coordinate with industry to see that this is carried out.

Upland Game Birds

The no-occupancy stipulation should be used to protect the large sage grouse breeding and nesting complexes and seep and wet meadow areas. The BLM should initiate studies to better define these areas.

Vegetation rehabilitation in game bird habitat should include seeding of important food and cover vegetation to satisfy the needs of sage grouse, chukar partridge and, where appropriate, other species.

Protection of all surface water as described for antelope under *Big Game* will also mitigate the impacts for upland game birds.

Waterfowl

Require installation of "flasher" fencing to scare off waterfowl on all pits, ponds, and reservoirs which will contain polluted or oily water.

Stipulate leases with "no occupancy" around reservoirs, ponds, and in riparian habitat along streams and rivers to avoid destruction of nesting habitat for waterfowl and to reduce human activity in these areas. Use appropriate stipulations (see Forms 3040-1, 3040-4, and WSO-2800-22, Appendix 2) to accomplish similar protection from oil and gas exploration, pipeline and road rights-of-way, and other activities when they are not covered by lease stipulations.

Protection of surface water as indicated in previous mitigation, especially the large ponds and reservoirs will mitigate the impact on waterfowl habitat. In addition, "safety" dams should be constructed downstream from pits or ponds to catch accidental spills when there is a good possibility that a spill could go into important waterfowl habitat.

Raptors and Others Birds

Ensure that all power networks in present and new development areas are designed or modified to incorporate raptor protection devices.

Rehabilitation of vegetation should be done with consideration for the needs of the species of birds using the area.

Ensure the maintenance and enhancement of water quality and quantity for small birds and shore birds.

Stipulate no-occupancy where human activity will disrupt important raptor nesting cliff areas or specifically identified eagle nesting sites. (See Ten Uniform Stipulations, especially #1, #3 and #7, Appendix 2.)

Predators and Furbearers

Large predators (bears, cougars, wolves, bobcats) will be protected from human disturbance in the areas covered by no-lease or no-occupancy stipulation for other wildlife values.

Mitigation measures which will protect water supplies and rehabilitate vegetation species for the benefit of animals which are prey species for large predators will also benefit the large predators.

Mitigation measures which protect riparian habitat should also be used to benefit furbearers such as beaver, muskrat and mink.

Small Mammals

Revegetation of any type will help mitigate small mammal habitat losses to some extent. Rehabilitate to like quality and quantity of vegetation to accommodate existing species of small mammals.

Protection of water sources and riparian habitat as indicated in previous mitigation will protect most species of small mammals.

If no-occupancy stipulations designed to protect black-footed ferrets are used, they will also benefit prairie dog populations.

Mitigation measures designed to minimize the amount of disturbance will minimize the losses of small mammals.

Reptiles and Amphibians

Those measures listed previously which are designed to protect surface waters will also protect amphibians and some reptiles.

Mitigation measures designed to minimize surface disturbance will also reduce impacts on reptiles and amphibians as will all stipulations requiring rehabilitation of vegetation.

Invertebrates

The Bureau should initiate studies to gather more information on the effects of produced water on aquatic invertebrates as they are important in many food chains.

Most of the mitigation measures previously mentioned which are designed to protect or reduce impacts on other animals will also protect invertebrates.

Fisheries

Denuded streambanks should be replanted with grasses, forbs, and shrubs. Where streambeds have been scoured, structures can be installed upstream to create pools (gabions, log and board dams or trash catchers), and spawning gravel can be placed in the streambed in the pools above the structures.

Material should not be removed from stream channels unless a permit is obtained by the permittee or lessee from the appropriate state agency, and a satisfactory plan to protect aquatic life and prevent siltation while removing the material has been approved.

Streams should not be channeled or relocated unless it is absolutely necessary to do so. In any case, advice and concurrence from DEQ should be obtained beforehand.

Road culverts should be designed and installed to allow fish passage.

Prevention of all accidents that result in oil pollution and harmful effects on aquatic wildlife is improbable, but their frequency and magnitude can be reduced by careful operation of drilling equipment and good maintenance procedures to prevent fires and explosions. Well blowouts can be reduced by the use of blowout preventors. Since it is most important from the standpoint of aquatic life to prevent oil from getting into streams or lakes, slant drilling could be required at specific sites to keep drilling operations further away from surface waters. In especially sensitive areas, secondary dikes can be constructed around the drilling site to contain oil in case of blowouts and during setting of drill cuttings. These measures can also alleviate increases in surface water temperatures.

Saline water contamination of streams and other surface waters can be reduced by locating drilling sites away from surface waters, using tanks to contain any liquids that flow from the well during drill stem testing, preventing blowouts during exploration and development — using blowout preventors, good safety practices, and recommended drilling techniques and casing the wells.

Surveys and monitoring of aquatic communities should be done by experienced biologists who will be able to evaluate the significance of population changes.

Ecological Interrelationships

All of the mitigation measures discussed in the various subheads of this section will function in partially mitigating impacts upon the various ecosystems.

Landscape Character, Recreation

The following actions are recommended for mitigating the adverse impacts in high quality recreation areas. Since policy decisions may prescribe a non-optimal course of action, secondary recommendations are in parentheses.

Legend Rock. Stipulate no surface occupancy without prior consultation with the Worland District Manager in conjunction with the district archaeologist. Preserve at

least a 300-foot buffer zone adjacent to the petroglyphs.

Gooseberry Badlands. Stipulate no road blading within this area. (If drill pad must be constructed, locate on north-facing slopes out of view of travelers on Highway 433.) Mandate prior district manager clearance in consultation with the landscape architect prior to surface disturbance.

Middle Fork, Fifteenmile Creek. Recommend that only stream crossings be bladed during preliminary exploration. Locate drill pads below and out of line of sight. (If development occurs, mandate construction standards which would enhance recreational access.)

Hillberry Rim. Recommend no surface occupancy on existing leases. (If occupancy is allowed, mandate district landscape architect's advice prior to allowing surface disturbance.)

Sugarloaf Mountain. Recommend no surface occupancy on ridgetops or upper third of slopes. Allow no disturbance which will be visible for over one-half mile. All projects will utilize terrain and vegetation to screen location; recreation planners or landscape architects can assist on location.

Castle Rock. Stipulate no surface occupancy. (If occupancy is permitted, allow no road construction and keep pad size to absolute minimum. Multi-discipline review will be mandatory in this area.)

North Fork, Owl Creek. Limit ingress and egress to existing roads and trails. Allow no developments which will be visible at a distance greater than one-half mile. All exploration will be cleared by district manager with review by area recreation planner, landscape architect, and soil specialist.

Upper drainages, Owl Creek tributaries. Recommend multi-discipline review of all proposals including at least the district landscape architect, vegetation specialist, soil specialist, and area outdoor recreation planner. Give district approval prior to any surface disturbance. Once the project is approved, allow no last minute modifications of proposals.

South Fork, Owl Creek. Allow no leasing in this area. (If area is leased already, allow no surface occupancy.)

Upper Gooseberry Creek. Recreation planner and landscape architect should be consulted prior to approving ingress and egress. Exploration should be supervised on the ground by the Worland District.

Cultural Resources

Cultural, historical, archaeological, and paleontological resources on federal land are protected under the Antiquities Act of 1906 (34 Stat. 225) and the Historic Sites Act of 1935 (49 Stat. 666). Particularly important to the protection of cultural resources on federally administered lands is the Historic Preservation Act of 1966 (80 Stat. 915) whereby all actions that will impact on the cultural resources must be reviewed by the President's Advisory Council on Historic Preservation prior to their implementation. Executive Order 11593 directs preservation of cultural values. These and other federal statutes afford varying degrees of protection by requiring the identification, evaluation, and protection of cultural resources that would be impacted by exploration for, and development or transportation of oil and gas energy minerals.

Mitigation is the alleviation or lessening of adverse impacts by avoidance, relocation, protection, or the collection of data, otherwise known as salvage. The extent that mitigation is carried out is in direct proportion to the significance of the resource being impacted.

Stipulations to protect known and unknown cultural resources can effectively protect their values. Adherence to and enforcement of federal and state laws and regulations such as the Antiquities Act and the Historic Preservation Act, along with non-intrusion on locales or areas containing cultural resources, can reduce or minimize the impacts caused by exploration and development activity. Cultural resource sites and objects revealed by exploration or development activities should be studied and evaluated prior to continuance of operations.

Roads developed in unproductive areas should be rehabilitated to avoid providing access to areas which may contain significant values.

Historical Resources

All mitigating measures described above also apply to historical resources. Since the impact on historical resources will in large measure be in proportion to the amount of surface disturbance, site specific detailed surveys, salvage, excavation, and possibly structure relocation may be required.

The impacts on historical resources of all on-site construction, operations, and transportation facilities can best be mitigated by avoidance.

If the historical values are on the National Register of Historic Places or eligible for nomination, a study will be conducted and forwarded to the President's Advisory Council on Historic Preservation for comment.

Paleontological Resources

Of very high value and great importance are the paleontological values known to exist in this area. Mitigating measures would involve paleontological surveys prior to oil and gas exploration, development, or transportation activities. If significant fossil remains are discovered, avoidance would be the most suitable mitigative posture. When avoidance is not possible, the salvage, excavation, and preservation of paleontological values could be required. Reports would be submitted on this work and the materials recovered would remain federal property. Significant fossils are deposited in appropriate scientific institutions.

Socio-Economics

The BLM should continue to keep the local communities informed as to projected oil and gas production so they can deal intelligently with problems associated with changing production levels. The BLM should cooperate with county planners in the development of recreation resources wherever possible subject to environmental and other land use constraints. (Refer to the section on Possible Mitigating or Enhancement Measures.)

RESIDUAL IMPACTS

Air Quality

Implementation of all of the recommended mitigating or enhancing measures would reduce but not eliminate the adverse impacts on air quality from oil and gas operations. There would still be some gaseous pollutant degradation of air quality resulting from internal combustion engines; waste gas release; burning of sludge; and any accidents such as fires or explosions. Most of the particulate impacts will remain, however, even after mitigation.

Soils

In the exploratory phase, tractor blade width seismic lines on a one- to two-mile grid would leave soil exposed to surface erosion. On more erodable soils or in non-regenerative climates, prohibition of blading between the shot holes would leave only minimal erosion at the 400- to 1400-foot spaced shot holes.

Overall residual erosion impacts from extensive exploration would be generally light although widespread.

Development, production, and abandonment can be considered together as all involve aspects of intensified construction. (Wildcat drilling exploration will be considered also in this discussion as it fits better here in terms of residual impacts than in exploration.)

The more serious impact that would occur despite mitigation in these phases are the clearing and movement of soil for access roads, trails, and flowlines. Yet, with the prescribed mitigation measures for location and construction practice, these impacts can be reduced from a potentially severe to a moderate level over a rehabilitation period ranging from one year for buried pipelines to 10 to 50 years from production facilities and major roads needed during the productive life of the field.

Scarification and revegetation steps would further reduce longer term erosional impacts to minimal levels with the exception of cases in which roads or other earthmoving has been improperly located on unstable ground.

The residual impacts likely to persist despite mitigation are more difficult to assess in the case of accidents such as blowouts, spills, leaks, or fires. Oil spills will generally have little impact directly on soil erosion and vegetative kill leading to erosion would be somewhat short term due to the biodegradability of crude petroleum. Spills of salt solutions and caustics, or hot fires may cause much longer periods of soil sterility with subsequent severe erosion on steeper sites.

Overall, unavoidable impacts from the development through abandonment phases of oil and gas production would tend to be moderate, within the drainage areas in which fields are developed. However, there inevitably would be isolated instances of localized severe erosional impacts due primarily to large accidents or unsupervised, improper construction or abandonment measures.

Geologic Structures

Impacts identified cannot be readily mitigated. Residual impacts to geological structures will be essentially the same as those identified in the anticipated impacts section.

Land Use

Application of the recommended mitigation will reduce some of the adverse impacts and possibly enhance some of the desirable impacts. Many of the anticipated impacts will remain.

Recreation

Roads and structures associated with oil and gas development change the character of the natural landscape. While increased access provides a beneficial impact to many recreational users (especially those using off-road vehicles for primary or secondary recreation purposes), the general impacts are adverse, at least until the abandonment stage. During development and operation, relatively small areas of several square miles are off limits to recreationists. In terms of casual sightseeing recreation, oil fields, and facilities are usually of interest, although travelers' reactions may be favorable or critical of such operations.

Mining

The unavoidable impacts on other mineral resources consist of the physical occupancy of potential mineral areas by oil and gas operations, accidental explosions, and fires in the area, and possible surface slumping.

The physical occupancy of the field, including areas for storage tank farms, collection and transmission lines, and other operational improvements, will preclude the use of the site for other mineral development for the producing life of the field. The influence of this occupancy will extend for some distance in all directions from the center of the field or operation. Refinery operations could have an effect for an even longer period of time.

Fires resulting from accidental explosions and other causes are unpredictable and in some cases unavoidable. Unavoidable fires in timber can be completely crippling to other mineral operations. These fires could not only deplete the supply of timber for mine timbers, but could damage an entire mining operation to such an extent that it would be unfeasible or uneconomical to repair or continue in operation.

Surface slumping can happen after oil field abandonment despite precautionary mitigation measures. The re-

sulting instability can make the area unsafe for the mining of other minerals.

Forest Products

Residual negative impacts during the exploration phase on timber production are generally minor and limited primarily to a temporary setback in timber production on relatively small areas. There is usually time to preharvest timber from oil field sites prior to development and to rehabilitate and reforest such areas after abandonment, except in cases of severe accidental oil spills, saline water contamination, soil compaction, or loss of soil. Rehabilitative success, therefore, varies between forest types depending upon the actions applied, and it may not be possible to entirely restore some areas to their original productivity.

Agriculture

Disruption of grazing or intensive agricultural practices on a short-term basis can be expected on all sites on which such use is taking place. Areas taken out of production (roads, drill pads, ponds, etc.) may be significant when the land is of high productivity and oil and gas production extends over a period of years.

Except for large explosions, fires, spills of oil, or other hazardous material, or severe compaction or loss of soil, the relative impact on a long-term basis is minimal.

Urban Uses

Unless very rigidly regulated, oil and gas development could precipitate serious land use conflicts when occurring in residential, commercial, or industrial areas. Oil and gas operations could be entirely out of character with residential land use in particular. Unavoidable explosions, fires, or other accidents could result in injury or death to humans.

Water

The residual impacts upon the water resources result from each of the discrete actions associated with oil and gas leasing. This section will analyze the impacts which will remain after mitigating measures have been implemented.

Exploration

The most significant impacts during the preliminary exploration phase are related to erosion and sediment yield. The BLM has responsibility for managing the land surface and can apply mitigating measures as needed. The amount of erosion and sediment yield was not quantified in the impact chapter and cannot, therefore, be quantified here. It is felt, however, that through vigorous enforcement of the recommended mitigation measures, erosion and sediment yield from preliminary exploration can be reduced by 60 to 80 percent; in some cases, after revegetation, erosion could actually be less than before the land disturbance.

The possible impacts resulting from mudpit fluids entering a live body of water will be almost entirely eliminated through vigorous enforcement of the recommended mitigating measures.

Development and Production

The most important unavoidable impacts on surface water quality would be associated with accidents in the development and production phases. These include oil spills, leaks, and blowouts. Contingency plans and safety measures such as protective dikes, standby clean-up equipment, etc., would reduce impact extent in terms of both volume and length of exposure to pollution.

The utilization of water resources for oil and gas exploration and development, that would be used for other purposes, could not be mitigated.

Reinjection Water

The reinjection of water is regulated by the USGS; possible impacts cannot be mitigated by BLM.

Discharge Water

The DEQ regulates the discharge water from oil fields through a permit system. The only mitigation measure which the Bureau can enforce is to limit the discharge of water on public lands. In most cases, this would have a negligible effect on the total water quality picture. Nearly all of the impacts of discharge water which were identified in the impact section would, therefore, continue.

Summary

Stream crossings will inevitably produce suspended sediment. The act of constructing adequate stream crossing structures and fords will increase suspended sediment during the construction phase. Unexpected or unusual peak flows may cause stream crossing structures to fail. These climatic events may also cause mudpits to overflow and the contents to enter stream channels. During heavy rains, failure of earthworks, which contain production water, may allow brine and oil to reach streams, lakes, and marshes.

Plants

Aquatic

Some increase in the growth of certain algae and moss will be observed due to the increase in water temperatures brought about by the discharge of treater water. Aquatic

vegetation will be adversely impacted by siltation resulting from soil disturbance.

The potential threat of a major oil spill reaching the streams and rivers would remain. Such a spill could adversely affect the aquatic flora to a significant degree.

Terrestrial

Vegetation will be lost due to the direct destruction of plant cover by construction of drill pads, roads, seismograph trails, drainage crossings, pipelines, and other structures. A lesser impact will occur to off-site vegetation, that is vegetation immediately adjacent to the disturbed site. Impacts to this vegetation will be in the form of competition from species which invade the disturbed area, loss of habitat from erosion, soil compaction and siltation, or from mechanical injury by equipment. Riparian vegetation along drainages receiving treater water may expand due to the increased water, but in the long term could possibly decrease if the water contains high concentrations of salts which would eventually make the site unhabitable.

Severe loss of vegetation could be incurred due to accidental blowouts, fires, oil spills of salt water or caustic solutions. Mitigating measures and cleanup contingency plans should minimize the probability of such occurrences. However, when these situations occur on much larger areas, vegetation can be lost for periods of from one to several years (in the case of fires or oil spills in easily regenerated environments) to much longer terms in the case of soil sterilization.

More thorough administration might reduce but would not eliminate the limited occurrence of these moderate to severe impacts.

In abandonment, available mitigation measures for vegetation rehabilitation should preclude any significant residual impacts except on the most sensitive sites or fragile areas. However, abandonment rehabilitation effectiveness is very much affected by administrative intensity. Therefore, light to moderate vegetative impacts are likely to remain due to the absence of or inadequate rehabilitative measures.

Wild Horses and Livestock

Wild horses will be disturbed to some extent by exploration activities and will be displaced for short periods. Domestic livestock is less apt to be affected in this way. Both horses and livestock will be affected by the vegetation loss caused by soil disturbance. Both will benefit to some extent from the increased availability of water which is discharged from treaters. Both will sustain an insignificant loss from traffic deaths associated with the oil and gas industry.

Fish and Wildlife

With judicious application of the various mitigation possibilities described for use in reducing wildlife impacts, a major part of the serious negative impacts can be eliminated. The residual impacts after mitigation efforts will in many cases depend upon how far management will go in limiting or modifying industrial activities. Assuming that recommended mitigation measures are thoroughly accepted and implemented, the following residual impacts on wildlife will still occur.

Direct mortality losses to most wildlife species will still occur as long as the project magnitude of industrial activity is not reduced. Most mortality of small animals will still remain about the same when heavy equipment destroys natural communities. Road kills and illegal shooting will remain a source of mortality to big game and many other animals. Where accidental spills of oil or toxic substances occur, there will still be losses, especially where the pollutants enter water sources. Fishes, amphibians, waterfowl, and aquatic mammals and insects will be destroyed in these instances. In spite of precaution, some spills such as these can be expected.

Where native vegetation is temporarily destroyed, the food and cover values are also destroyed for a variety of species. The annual "crop" of these wildlife species will be eliminated or reduced for some number of years until the habitat naturally comes back or is restored. The original annual wildlife production potential is lost for some period of time depending on the type of vegetation destroyed and the types of wildlife dependent upon it. If the habitat is destroyed to start with, this impact is unavoidable. Production of wildlife species such as deer and others dependent upon long-lived plants, such as shrubs and trees, will be eliminated or reduced for longer periods of time. It may take decades to reestablish timber or browse communities. It is estimated that mitigation could reduce this type of impact to about 25 percent of that which could be expected without the mitigation described.

Habitat amounting to about 1,500 acres over ten years is expected to become permanently lost to facilities such as major roads and buildings. Impacts from this type of habitat loss can be reduced for some species by no-lease, no-occupancy, or other type stipulations; but if the industry operates at all, some species will suffer. Impacts can be reduced somewhat, but primarily it will be a matter of trade-offs of impacts on one species of wildlife for impacts on another species.

Where concentrated development and human activity accompanies industry activity, habitat for certain species will still be rendered useless over considerable acreages. Mitigation, which will help to ensure these developments take place in less important wildlife areas, will reduce negative impacts. It is estimated that a minimum of 25 percent of this type impact will be unavoidable.

With abandonment of fields such as Hamilton Dome, the loss of production water will negatively impact waterfowl, fish, reptiles, and amphibians and aquatic insects over many miles of stream drainages presently watered from these sources. It appears that impacts on these species in these waters will be unavoidable.

Ecological Interrelationships

Any human activity that alters the abiotic environment or biotic community can impair ecological relationships to

some degree; mitigative measures cannot be entirely effective. Despite all feasible precautions, some oil and gas operations will upset the natural balance of ecosystems at least temporarily. Actions or accidents which destroy vegetation, disturb soil, degrade water quality, and pollute the air will cause some disruption of ecological interrelationships. In these instances, the nutrient cycle and hydrologic cycle may be interrupted until the affected area is revegetated and soil is stabilized, or until the source of pollution is removed.

Fragile ecosystems, where productivity is low and the natural balance delicate, will be most severely impacted and slowest to recover, particularly where the ecological equilibrium has been impaired by other human activity prior to oil and gas operations. If grazing, road construction, logging, mining, recreation, etc., have already affected ecological interrelationships, the added impact of oil and gas operations may create a total cumulative effect that may not be offset by mitigative measures.

Landscape Character, Recreation

If the recommended mitigating measures are fully implemented, the residual impacts of oil and gas leasing and production versus landscape character and recreation values will be as follows.

Legend Rock Petroglyph Site may be degraded if a well is placed in the creek bottom 300 feet from the site. The petroglyphs will remain intact, but interpretation will be adversely limited.

The badlands between East Ridge and State Highway 431 will not show any disturbance to the motorists on the road. However, roadless or primitive values may be sacrificed if intensive exploration occurs.

The middle fork of Fifteenmile Creek would possibly lose its potential for wilderness designation. At least a 28,000-acre unit worthy of roadless designation would be lost. Conversely, four-wheel-drive and dirt bike enthusiasts would benefit from improved access and overall visitor use would likely increase over several decades as compared to back country use.

No residual impacts would remain on or near Hillberry Rim.

Sugarloaf Mountain and upper Cottonwood Creek drainage would have visual scars seen only for a short distance. Better access for hunters would probably increase deer and elk harvests in the area.

If no occupancy occurs, Castle Rocks and their vicinity would be unaffected. If any development occurs, a several-thousand-acre, sub-alpine primitive area would be lost.

The upper end of the north fork of Owl Creek is undeveloped. Any construction on this drainage (even if mitigated as proposed) would result in long-term visual scars and would radically alter the primitive values in this drainage.

The area north of Split Rock Creek would lose its potential for designation as a roadless or primitive area.

If no leasing is allowed, the south fork canyon of Owl Creek will be unaffected.

Residual but substantially unnoticeable visual intrusions would occur in the upper Gooseberry Creek drainage.

Outside of the high value areas described above, residual impacts would occur on other landscape and recreation values. Landscapes within existing KGSs would become increasingly industrialized. New fields in undeveloped areas of low value might add or detract from the area's interest, depending on location, interpretation, and resources at the specific location. If properly interpreted, some beneficial understanding of the oil industry might result.

Any disturbance in areas above 7,000 feet elevation would degrade the undeveloped character of the lands outside known KGSs. Roads would continue to benefit recreationists through their degree of safety, signing, and allowing for physical and sometimes legal access. Also, increased discharge flows will benefit recreationists to the degree they support stable stream flows or fish populations in the unit.

Cultural Resources

Impacts on the archaeological environment that cannot be mitigated are those associated with surface disturbance. The threat of inadvertent utilization of terrain hosting undetected archaeological, paleontological, or historical values will always remain despite reconnaissance and clearance, even by skilled professionals. Also, the opening up of previously inaccessible areas by road construction to general traffic would subject archaeological, historical, and paleontological values to vandalism and change.

Socio-Economics

The residual economic impacts of oil and gas activities in the Grass Creek study area are contingent on the scope of mitigation taken and the degree of success encountered. None of the mitigative actions suggested will completely remedy all of the impacts cited and it is possible that no action will be undertaken by the state or local governments involved.

There will be a reduction of economic activities in oil and gas and in supportive economic functions, as well as a substantial reduction in revenue to the county which not even the best fiscal planning will mitigate. However, the negative impacts related to the withdrawal of the economic benefits of oil and gas are minimal when compared to the positive economic benefits that occur to the community during the lifetime of the project.

Safety is an additional consideration that needs to be addressed. Personnel working the oil and gas development are subject to a variety of hazards, particularly in the drilling phases of the operation. Hydrogen sulfide gas poses a severe threat to workers during both the drilling and production phases. Hazards to workers' health and safety are primarily the responsibility of the U.S. Geological Survey and the Occupational Safety and Health Agency. Despite the efforts of these agencies and the efforts of the industry itself, some accidents will continue to occur.

SHORT-TERM USE VERSUS LONG-TERM PRODUCTIVITY

Short-term use will consist of occupying the land for the purpose of production of oil and gas for a period of years until the oil supply is depleted to a point where it is no longer economically feasible to produce. Long-term productivity is the continued use of the land by other activities such as grazing, wildlife use, and recreation. These uses are presently being made of the land and will continue after oil and gas production ceases.

The impact on air quality by gaseous pollutants will be relatively short-term and will primarily exist only when oil production is continuing. Revegetation/rehabilitation of drill pads and other disturbed areas will result in a reduction of some of the dust pollution. However, some pollution by dust and gaseous emissions due to ORV traffic related to increased access will continue after oil production ceases.

Much of the land which is now committed solely to single use for oil and gas production will become available for other uses as wells are abandoned. However, some of the permanent structures such as roads will not be removed and will continue to exist long after oil and gas production ceases.

Water quality will be affected similarly to air quality in that the impact on water will greatly decrease when oil production ceases, but some water pollution will continue to occur through runoff from disturbed areas until those areas are revegetated. Toxic substances deposited in drainages by produced water will continue to pollute natural runoff for long periods after the production of water ceases.

Production of vegetation will never return to the level existing prior to oil and gas production because of the permanent structures which will remain and which will not allow vegetative growth. As wells are abandoned, disturbed areas will be revegetated and returned to production. However, these sites may not return to the same level of production as before oil production began. Some of the sites could possibly produce more vegetation and some will undoubtedly produce less. In most cases, the plant community on these disturbed areas will be changed due to the availability of seed, difficulty of reestablishing some of the native species, and changes in soil texture and structure which will permanently affect vegetation compositions.

Use by animals — both wild and domestic — is greatly dependent upon the vegetation present and the success in reestablishing vegetation.

Short-term use of the lands for general exploration activities will not, as a rule, impair long-term productivity for wildlife, with the exception of some endangered species. If oil is found, however, subsequent development and production can have a long-term effect on wildlife through loss of crucial wintering, breeding, production, and migration areas. In these cases, both the habitat and wildlife can be lost. After production and site abandonment, the ecosystem may never be entirely rehabilitated. Human settlement that takes place during development and production may persist after petroleum production has been exhausted. Thus, wildlife formerly found in the area may never again use it due to changes in land patterns and use.

Smaller, more adaptive wildlife species such as ground squirrels, rabbits and other mammals, birds, and insects, and the small predators that depend on them, may reinhabit the peripheral zones of their former habitat. Exotics such as pheasants, chukar, and Hungarian partridges may find the change in land patterns to their liking, especially if agricultural development has occurred.

The long-term ecological impact on streams and lakes is one of reduced production of indigenous cold water fishes. Habitat conditions become favorable for non-game species that thrive in warm waters, while preferred cold water species are either reduced in numbers or eliminated from the area. Some aquatic insects and benthic organisms are affected in a similar manner by drastic changes in habitat conditions caused by sedimentation.

Productivity is usually indicative of an ecosystem's stability. Highly productive ecosystems are generally in good equilibrium, while the natural balance is fragile in communities of low productivity (Darling and Milton, 1966; Kormondy, 1969).

Visual resources will be permanently altered by development and road and pipeline construction. The flow of goods and services dependent upon oil and gas production will gradually decrease as production diminishes.

Cultural Resources

Short-term use of oil and gas sites with archaeological resources can sometimes be beneficial, particularly in areas where little knowledge has been previously available. This can serve as the basis for long-term planning for the total archaeological resource. On the other hand, short-term use may represent the least efficient use of the archaeological resource because of the state-of-the-art at time of discovery and the "hurry-up" protection and salvage methods dictated.

Short-term uses that alter or destroy archaeological sites will, of course, have long-term impacts on the productive value of those resources.

Danger of short-term or long-term impacts to historical values can be minimized if proper care is exercised. The greatest danger is complete loss of an historical value by obliteration due to lack of knowledge of its existence.

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The most apparent commitment of resources is the extraction and eventual consumption of oil and gas from the area. However, massive erosion destruction of human interest values, elimination of endangered species, and irrevocable changes in land use would also fall within this section. Existing fields have thus far produced approximately 403 million barrels of oil and 489 billion cubic feet of natural gas. It is estimated that continued leasing of federal oil and gas will eventually result in the extraction of 40

to 60 percent of the total oil and gas reserve in the area, assuming no major changes in extraction technology. There is a substantial amount of fossil fuel and electrical power expended in all phases of oil and gas production.

Paleontological and archaeological resources are subject to partial or total destruction by any surface or subsurface disturbance if they have not been identified and excluded in the plan of operation. If salvage of these sites is done hastily preceeding oil and gas exploration or development, there is a chance that maximum values of more deliberate work would not be attained.

The vegetation and animals lost to oil and gas activities can in theory be replaced by rehabilitating the sites. However, the growth lost during the period when the site is not producing can never be replaced.

Excessive sedimentation can cause irretrievable changes in aquatic habitat when stream channels, lakes, marshes or reservoirs become filled with sediment. These habitats are no longer capable of producing the quantities of fish they once did unless the sediment is physically removed, which is generally considered impractical.

During the period of field and related operation, loss of soil covered by structures, roads, and facilities would be irreversible. Some areas heavily oil soaked or eroded away would represent irreversible losses. Due to accidents and failures, surface reservoirs can suffer permanent loss of storage capacity because of increased sedimentation. Ground water aquifers can suffer permanent loss of water quality because of contamination with pollutants.

If subsidence occurs in formations containing underground water aquifers during the life of the field, the aquifer would be irretrievably lost. Subsidence cannot be reversed, nor can aquifers where subsidence occurs be recharged.

PERSONS, GROUPS, AND AGENCIES CONSULTED

Northwest Analytical Laboratory	Powell, WY
Chemical and Geological Laboratories	Casper, WY
Water Resource Research Institute	Laramie, WY
Steve Glasser, hydrologist, Shoshoni Natl. Forest	Cody, WY
Thomas Richmond, USGS	Thermopolis, WY
Earl Speiles, Marathon Oil Company	Casper, WY
John Brooks, Marathon Oil Company	Grass Creek, WY
Harold Harris, Atlantic Richfield Oil Co.	Hamilton Dome, WY
H. P. Quarles, Ashland Oil Company	Hamilton Dome, WY
S. M. Haynes, Westates Oil Company	Hamilton Dome, WY
J. E. Whitman, Conoco Oil Company	Casper, WY
John O. Goffe, Marathon Oil Company	Casper, WY
Donald L. Armstrong, DEQ, Water Quality Division	Cheyenne, WY
Robert J. Schick, DEQ, Air Quality Division	Cheyenne, WY
A. E. King, Commissioner of Public Lands	Cheyenne, WY
Donald B. Basko, State Oil and Gas Supervisor	Casper, WY
Calvin King, Wyoming Game and Fish Dept.	Thermopolis, WY
William Dooley, Wyoming Game and Fish Dept.	Meeteetse, WY
Louis Pechacek, Wyoming Game and Fish Dept.	Cody, WY
Tim Britt, Wyoming Game and Fish Dept.	Lovell, WY
Dan Healy, rancher	Worland, WY
Terry Martin, Petroleum Association	Casper, WY

INTENSITY OF PUBLIC INTEREST

The oil and gas industry has been in the Grass Creek area since 1914; and due to this long-term use has become a part of the local scene. Although we have not yet formally requested input from interested parties, no great public interest in oil and gas activities has been evidenced outside the general increase in the environmental awareness that has taken place throughout the country. Increased environmental protection is, however, evidenced by the oil and gas industry in its efforts to improve exploration and production techniques to lessen the environmental degradation.

Locally, the discharge or produced water has aroused some controversy among ranchers and farmers. There are those who believe the water is detrimental to livestock due to its quality versus the benefits to livestock and wildlife because of availability. This water makes otherwise unusable rangeland usable. Improved treatment of this water in the last few years has probably lessened this controversy somewhat.

This document will be circulated to representatives of the oil and gas industry, government agencies and other interest groups for comment. Comments will then be analyzed and where applicable, incorporated into the process of oil and gas leasing and management.

SUMMARY CONCLUSION

Soil disturbance and soil compaction resulting from oil and gas exploration and production activities such as seismographing, exploratory drilling, and production will have an impact on many segments of the environment. Disturbance and compaction of the soil will result in a loss of plant growth — primarily short term, but in some cases long term — and will in many cases cause a species or type change. This loss of plant growth will have a direct effect on domestic livestock and nearly all species of wildlife. The loss of cover often causes increased erosion which in turn results in lessened water quality in some cases. Much of the impact to the environment can be lessened through proper planning and location of activities and immediate and effective rehabilitation of disturbed sites.

Oil and gas production as a land use is in some cases not compatible with other land uses. Most notable are wildlife, especially the more easily disturbed species such as elk, and visual resources along some well-traveled corridors in otherwise undeveloped areas. Oil and gas production is compatible and highly beneficial to many land uses, primarily because of the access provided by oil companies in constructing roads to production sites. These roads are used by many land users; most notable among these are hunters and many other recreationists, livestock managers, and in some cases, timber harvesters.

The production and surface discharge of treated water can be beneficial to many species of wildlife and livestock if it is properly treated and the oil and gas content sufficiently low. In sufficient quantities, this water is also beneficial for irrigation of agricultural crops.

The oil and gas industry is basic to the economy of the community. All phases of the industry furnish employment to local residents as well as transient laborers. Wages paid are a vital link in the flow of goods and services in the community. Revenues from royalties furnish a significant portion of the state and county budgets and are important to the operation of the local governments.

While there has been production of oil and gas in the Grass Creek area for over 50 years, the production from a given well is relatively short term, and eventually the oil and gas reserves will be depleted and production will cease. While many of the more permanent facilities such as roads will remain, the surface use of the land will change from oil and gas production to the most suitable use or uses.

Extraction of oil and gas requires a commitment of resources which is not retrievable. Primary among these resources is the energy expended in the form of fuel and electricity for extraction and the commitment of surface use to permanent structures such as roads. While in theory structures such as these roads can be removed, in actual practice they probably will not be.

Oil and gas production has been an ongoing industry in the Grass Creek area for over 50 years and has become a way of life in the Basin. In general, the public feels the benefits attached to oil and gas production outweigh the drawbacks, providing the protection of the environment is considered and extraction is done with the least amount of environmental degradation.

APPENDICES

Appendix 1

Oil and Gas Production
in
Grass Creek Planning Unit

APPENDIX 1

Oil and Gas Production in Grass Creek Planning Unit (through 1976[1])

Field (KGS)	County	Date	T&R	No. of Prod. Wells	Prod. Dec. 1976 Oil — bbl[3] Gas — MCF[4]	Prod. 1976 Oil — bbls Gas — MCF	Prod. Tot. Cum. Oil — bbls Gas — MCF	Remarks
Aspen Creek	Hot Springs	1974	45-101	2	5,597	38,111	79,365	oil
					0	0	0	gas
Baird Peak	Hot Springs	1964	45-100	1	32	558	58,251	oil
					0	0	0	gas
Dickie	Hot Springs	1953	45-101	0[2]	0	0	52,238	oil
					0	0	0	gas
Enos Creek	Hot Springs	1923	46-100	2	850	10,181	747,735	oil
					22	260	49,898	gas
Fivemile	Big Horn	1952	49-93	1	427	3,393	231,298	oil
					10,076	108,636	7,401,695	gas
Fourteenmile	Washakie	1952	46-94	0[3]	0	0	95,120	oil
					0	0	139,831	gas
Gebo	Hot Springs	1943	44-95	50	50,448	589,199	22,813,416	oil
					1,533	22,088	766,240	gas
Golden Eagle	Hot Springs	1921	45-97	8	9,804	114,456	12,705,376	oil
					5,053	59,945	2,332,873	gas
Gooseberry	Park	1937	46,47-100	12	14,808	160,460	5,207,686	oil
					0	0	43,340	gas
Grass Creek	Hot Springs	1914	46-98	237	370,100	3,918,786	147,257,707	oil
					10,656	116,090	5,636,057	gas
Hamilton Dome	Hot Springs	1918	44-97,98	241	227,589	6,987,830	119,113,510	oil
					1,393	17,222	62,831	gas
King Dome	Hot Springs	1964	44-96	2	1,796	11,184	76,512	oil
					0	0	170	gas
Little Buffalo	Park	1914	47-98	117	493,349	5,052,104	66,405,715	oil
Basin			47,48-100		39,201	550,368	114,383,626	gas
Little Grass	Hot Springs	1917	46-99	1	0	0	0	oil
Creek					15,953	183,206	7,299,452	gas
Little Sand	Hot Springs	1949	44-96	9	13,642	161,654	5,507,838	oil
Draw					0	0	0	gas

APPENDIX 1 (con't)

Field (KGS)	County	Date	T&R	No. of Prod. Wells	Prod. Dec. 1976 Oil — bbl[3] Gas — MCF[4]	Prod. 1976 Oil — bbls Gas — MCF	Prod. Tot. Cum. Oil — bbls Gas — MCF	Remarks
Meeteetse	Park	1954	44-99	1	794	9,225	186,173	oil
					0	0	835	gas
Prospect Creek	Hot Springs	1963	45-100	5	2,251	29,437	133,916	oil
					0	0	0	gas
Skelton Dome	Hot Springs	1954	45-99	1	0	0	0	oil
					3,286	7,611	64,481	gas
Sunshine N	Park	1928	47-101	9	3,591	33,168	1,190,354	oil
					0	0	0	gas
Sunshine S	Park	1926	46-101	1	372	4,948	291,062	oil
					0	0	0	gas
Wagonhound	Hot Springs	1944	44-98	1	197	3,574	500,013	oil
					247	4,396	8,225	gas
Walker Dome	Hot Springs	1930	46-99	8	3,643	59,145	2,596,222	oil
					518	7,970	748,449	gas
Waugh	Hot Springs	1934	44-96,97	3	2,833	27,949	793,827	oil
					0	0	168,779	gas
Worland	Washakie	1946	48-92	27	13,364	165,669	17,278,139	oil
					633,643	8,098,869	349,997,798	gas
	TOTALS			739	1,215,487	17,381,031	403,321,473	oil
					721,581	9,176,661	489,103,580	gas

[1]From Wyo. Oil and Gas Commission annual production
[2]Abandoned 1958
[3]Abandoned 1961
[4]Barrels
[5]Million Cubic Feet

Appendix 2

Standard Forms Used in Leasing Process

Form 3040–1
(November 1970)
(formerly 3107–1)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

NOTICE OF INTENT TO CONDUCT OIL AND GAS EXPLORATION OPERATIONS

Name	Address *(include zip code)*

hereby files this "Notice of Intent to Conduct Oil and Gas Exploration Operations" across and upon *(give description of lands by township(s) and range)*

The type of operation to be pursued is ☐ magnetometer ☐ seismograph ☐ other *(specify)*

Approximate date of commencement of operations Upon completion of work, the Bureau of Land Management District Manager shall be furnished a "Notice of Completion of Oil and Gas Exploration Operations."

The undersigned agrees that oil and gas exploration operations will be conducted pursuant to the following terms and conditions:

1. Exploration operations shall be conducted in compliance with all Federal, State and County laws, ordinances or regulations which are applicable to the area of operations including, but not limited to, those pertaining to fire, sanitation, conservation, water pollution, fish and game. All operations hereunder shall be conducted in a prudent manner.
2. Due care will be exercised in protecting lands in this notice. All necessary precautions shall be taken to avoid any damage other than normal wear and tear, to gates, bridges, roads, culverts, cattle guards, fences, dams, dykes, vegetative cover and improvements, and stock watering and other facilities.
3. Appropriate procedures shall be taken to protect any shafts, pits or tunnels, and shot holes shall be capped when not in use to protect the lives, safety, or property of other persons or of wildlife and livestock.
4. All vehicles shall be operated at a reasonable rate of speed, and due care must be taken to safeguard all livestock and wildlife in the vicinity of his operations. Bulldozers shall not be used without advance notification to the District Manager. Existing roads and trails shall be used wherever possible; if new roads and trails are made, care should be taken to follow natural contours of the lands where feasible and restoration and/or reseeding, as requested by District Manager shall be made.
5. Upon expiration, revocation or abandonment of operations conducted pursuant to this "Notice," all equipment shall be removed from the land and the land shall be restored as nearly as practicable to its original condition by such measures as the District Manager may specify. All geophysical holes must be safely plugged. Upon leaving the land, the District Manager shall be informed.
6. Upon request, the location and depth of water sands encountered shall be disclosed to the District Manager.
7. The party conducting such operations shall contact the District Manager prior to actual entry upon the land in order to be apprised of the practices which should be followed or avoided in the conduct of his operations in order to minimize damages to property of the United States.

(Signature)	(Signature of Geophysical Operator)
(Address including zip code)	(Address including zip code)

GPO 831-359

Form 3040–4
(November 1970)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

MINERAL LEASING STIPULATIONS

SURFACE MANAGEMENT REQUIREMENTS FOR EXPLORATION, MINING, AND RECLAMATION

Stipulations may be selected from the following list for inclusion in permits or leases. Care must be exercised to assure that any stipulation used apply specifically to the need for such stipulation. Other stipulations may be drafted as needed to meet specific problems.

1. Activities employing wheeled or tracked vehicles shall be conducted in accordance with industry practices and in such a manner as to minimize surface damage.

2. Trail widths shall be kept to the minimum necessary and may not exceed   feet. Surface may be cleared of timber, stumps, and snags. Care must be taken to avoid scarring or removal of ground vegetative cover.

3. Drainage systems shall not be blocked. No cuts or fills shall be made near or in streams which will result in siltation or accumulation of debris. All damage to streams must be repaired to the satisfaction of the authorized officer.

4. All operations must be conducted so as not to change the character or cause pollution of streams, lakes, ponds, waterholes, seeps, and marshes or cause damage to fish and wildlife resources.

5. Surface damage which causes soil movement and/or water pollution must be corrected to the satisfaction of the authorized officer.

6. Vegetation must not be disturbed within 300 feet of any waters designated in a (prospecting permit) (lease) (contract) *except* at authorized stream crossings.

7. No explosives may be used without prior written consent of the authorized officer.

8. Trails and campsites must be kept clean. All garbage and foreign debris must be eliminated by removal or burial. Burning is permissible only by prior written consent of the authorized officer.

9. Existing roads and trails shall be used whenever possible.

10. All survey monuments, witness corners, reference monuments, and bearing trees must be protected against destruction, obliteration, or damage. Any damaged or obliterated markers must be reestablished in accordance with accepted survey practices at expense of (permittee) (contractor) (lessee).

11. The operator shall make every effort to prevent, control, or suppress any fire in the operating area. Reports of uncontrolled fires must be immediately sent to the authorized officer or his representatives.

12. Fill all holes, pits, and excavations to the extent agreed in the approved mining plan and grade to the natural contour.

13. When surface operations are conducted, overburden or other waste shall be returned to the excavation, as set forth in the mining plan and except in instances when the district manager or state director determines that it would be desirable to use an excavation for the permanent impoundment of water or for other beneficial uses.

14. Disposal sites shall be selected and prepared so as to avoid downward percolation of pollutants into aquifers.

15. Disposal systems for solid and liquid wastes shall be designed and constructed so as to avoid landslides, control wind and water erosion, and establish conditions conducive to vegetative growth in the disposal area.

16. Casual accumulations of water on waste piles shall be avoided, and, where necessary, surface waters shall be directed around the piles.

17. Final grading of backfilled and other unconsolidated materials shall be so performed as to present a surface susceptible to vegetation or desired land form.

18. Excavations used for the permanent impoundment of water shall be graded to establish safe access to water for persons, livestock, and wildlife.

19. No solid rock face or bench face shall exceed   feet in height. Appropriate access suitable for persons, lifestock, and wildlife shall be provided for every   feet of continuous rock or bench face.

20. Except for solid rock faces, bench faces, and excavations used for impoundment of water, those surface areas of the leased premises disturbed by operations conducted by the lessee shall be revegetated when their use is no longer required by the operator. *(Species, methods, and season of seeding or planting, etc. should be specified. These requirements should be practical and generally should not require vegetative rehabilitation beyond level of production.)*

21. Backfilling, final grading, and vegetation shall be completed within two (2) years after the completion or termination of the particular operation involved unless the district manager extends the time.

22. Drill holes shall be permanently sealed or filled as directed by the district manager upon completion of operations.

23. Surface buildings, supporting facilities, and other structures which are not required for particular operations shall be removed and the area graded and revegetated.

24. All operations shall be conducted with a view to avoidance of range and forest fires and spontaneous combustion. Open burning of carbonaceous materials shall be in accordance with suitable practices for fire prevention and control.

25. The lease or contract premises shall be appropriately posted and fenced or otherwise protected to minimize injury to persons, livestock, and wildlife.

26. All access, haul, and other support roads and trails shall be constructed and maintained in such a manner as to control and minimize channeling and other erosion. Roads and trails shall be constructed only at locations approved by the authorized officer.

27. All roads constructed in the operation shall be closed by barricades or protected from erosion by placing of water control bars as required by the district manager.

28. All existing improvements including, but not limited to, fences, gates, cattle guards, roads, trails, culverts, pipelines, bridges, public land survey monuments, and water development and control structures shall be maintained in serviceable condition. Damaged or destroyed improvements shall be replaced, restored, or appropriately compensated for.

29. When agreed by lessee and lessor, the lease site shall be available for other public uses including, but not limited to, livestock, grazing, hunting, fishing, camping, hiking, and picnicking.

30. Topsoil shall be removed and stockpiled prior to removal of overburden. Stockpiles shall be located so as not to be covered by spoil materials and to facilitate their use in final backfilling and grading.

GPO 831-559

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

NOTICE OF COMPLETION OF OIL AND GAS EXPLORATION OPERATIONS

Name	Address *(include zip code)*

Pursuant to the notice heretofore filed to conduct oil and gas exploration operations, this is to advise that such operations were completed on , on the lands described in the previous notice.

(Signature) (Geophysical Operator)

(Address including zip code) (Address including zip code)

GPO 849-518

Form 3045-2 (January 1973) (formerly 3107-2)

DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Case Serial No.____________
Line I.D. Number(s)________

PERMIT FOR USE OF EARTHMOVING EQUIPMENT DURING GEOPHYSICAL EXPLORATION OPERATIONS ON NATIONAL RESOURCE LANDS IN WYOMING

____
Name, Address, and Telephone Number of Company Filing the Notice of Intent

____
Seismic Company, Party Chief, Name, and Telephone Number

______________________ ______________________
Sub-Contracting Company / Equipment Operator's Name

Location:______________________________________

Permission is hereby granted for the following use(s) of the earthmoving equipment:

____ Snow removal provided that the blade is kept at least six (6) inches above the soil surface.

____ Trail breaking for other vehicles without use of the blade.

____ Construction of ford-type crossings on drainages which cannot otherwise be crossed, only if there are no usable fords present in the area. The top 4-6" of surface soil material will be stockpiled on both sides of the crossing and replaced on the surface at the time of rehabilitation. Where feasible, all cuts will be made to the bottom of the creek bed. (Provide operator with "Typical Dry Creek Drainage Crossing" drawing.)

____ Other (Be specific)

This permit expires (estimated time of completion) on ____________________

I hereby agree to conduct operations only as permitted above.

______________________ ______________________
Equipment Operator / Party Chief

______________________ ______________________
District Manager's Representative / Date

(Complete this form in duplicate)

WY-3045-4 (Jan 1977)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

SURFACE DISTURBANCE STIPULATIONS

Area Oil and Gas Supervisor or District Engineer *(Address, include zip code)*

Management Agency *(name)*	Address *(include zip code)*

1. Notwithstanding any provision of this lease to the contrary, any drilling, construction, or other operation on the leased lands that will disturb the surface thereof or otherwise affect the environment, hereinafter called "surface disturbing operation," conducted by lessee shall be subject, as set forth in this stipulation, to prior approval of such operation by the Area Oil and Gas Supervisor in consultation with appropriate surface management agency and to such reasonable conditions, not inconsistent with the purposes for which this lease is issued, as the Supervisor may require to protect the surface of the leased lands and the environment.

2. Prior to entry upon the land or the disturbance of the surface thereof for drilling or other purposes, lessee shall submit for approval two (2) copies of a map and explanation of the nature of the anticipated activity and surface disturbance to the District Engineer or Area Oil and Gas Supervisor, as appropriate, and will also furnish the appropriate surface management agency named above, with a copy of such map and explanation.

An environmental analysis will be made by the Geological Survey in consultation with the appropriate surface management agency for the purpose of assuring proper protection of the surface, the natural resources, the environment, existing improvements, and for assuring timely reclamation of disturbed lands.

3. Upon completion of said environmental analysis, the District Engineer or Area Oil and Gas Supervisor, as appropriate, shall notify lessee of the conditions, if any, to which the proposed surface disturbing operations will be subject.

Said conditions may relate to any of the following:

(a) Location of drilling or other exploratory or developmental operations or the manner in which they are to be conducted;

(b) Types of vehicles that may be used and areas in which they may be used; and

(c) Manner or location in which improvements such as roads, buildings, pipelines, or other improvements are to be constructed.

Form 3109–5 (August 1973)

GPO 849-258

DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Serial No.______________

STIPULATIONS

OIL AND GAS PIPELINE RIGHTS-OF-WAY

1. This right-of-way is subject to all applicable regulations in 43 CFR Part 2800 and future regulations to be promulgated pursuant to the Act of November 16, 1973.

2. This right-of-way is subject to the express covenant that it will be modified, adapted, or discontinued if found by the Secretary to be necessary, without liability or expense to the United States, so as not to conflict with the use and occupancy of the land for any authorized works which may be hereafter constructed thereon under the authority of the United States.

3. The grantee shall survey and clearly flag the exterior limits of the right-of-way. All activities directly or indirectly associated with the construction or maintenance of this facility must be conducted within the limits of the right-of-way. If the grantee plans to install right-of-way or line markers, the number, size, height, type, and color of these markers must be approved by the District Manager, Bureau of Land Management.

4. No payment or other consideration will be made by the grantee to other users, licensees, permittees or lessees for any damage to or loss of natural vegetation, wildlife, mineral material, or for soil disturbance occurring on national resource lands, which result from operation, development or construction activities carried out under the authority of this right-of-way.

5. This right-of-way is subject to provisions of the Act of November 16, 1973, including:

    (a) Grantee shall take all measures necessary to protect the health and safety of all persons affected by their activities performed in connection with the construction, operation, maintenance or termination of the right-of-way grant, and shall immediately abate any health or safety hazards. Permittee shall immediately notify the District Manager of all serious accidents which occur in connection with such activities.

    (b) Upon demand of the authorized officer, the holder of the right-of-way shall pay to the United States such sums as the authorized officer shall determine to be required to reimburse the United States for all administrative and other costs incurred directly or indirectly by the United States in monitoring the construction, operation, maintenance, and termination of the facilities covered by this grant.

    (c) Abandonment of a right-of-way or noncompliance with any provision of Section 28 of the Mineral Leasing Act, as amended, or terms and conditions of this grant may be grounds for suspension or termination of the right-of-way if (A) after due notice to the holder of the right-of-way, (B) a reasonable opportunity to comply, and (C) an appropriate administrative proceeding pursuant to Title 5, United States Code, Section 554, the authorized officer determines that any such ground exists and that suspension or termination is justified.

    If the authorized officer determines that an immediate temporary suspension of activities within a right-of-way or permit area is necessary to protect public health or safety or the environment, he may abate such activities prior to an administrative proceeding.

    Deliberate failure of the holder to use the right-of-way for the purpose for which it was granted or renewed for any continuous two-year period shall constitute a rebuttable resumption of abandonment of the right-of-way.

    (d) There is reserved to the United States the right to grant additional permits or rights-of-way for compatible uses on or adjacent to the lands included in this grant.

    (e) Pipelines and related facilities authorized under this section shall be constructed, operated, and maintained as common carriers. The owners or operators of pipelines subject to this section shall accept, convey, transport, or purchase without discrimination all oil or gas delivered to the pipeline without regard to whether such oil or gas was produced on Federal or non-Federal lands. In the case of oil or gas produced from Federal lands or from the resources on the Federal lands in the vicinity of the pipeline, the Secretary may, after a full hearing with due notice thereof to the interested

parties and a proper finding of facts, determine the proportionate amounts to be accepted, conveyed, transported or purchased. The common carrier provisions of this section shall not apply to any natural gas pipeline operated by any person subject to regulation under the Natural Gas Act or by any public utility subject to regulation by a State or municipal regulatory agency having jurisdiction to regulate the rates and charges for the sale of natural gas to consumers within the State or municipality. Where natural gas not subject to State regulatory or conservation laws governing its purchase by pipelines is offered for sale, each such pipeline shall purchase, without discrimination, any such natural gas produced in the vicinity of the pipeline. Whenever the Secretary has reason to believe that any owner or operator subject to this section is not operating any oil or gas pipeline in complete accord with its obligations as a common carrier hereunder, he may request the Attorney General to prosecute an appropriate proceeding before the Interstate Commerce Commission or Federal Power Commission or any appropriate State agency or the United States district court for the district in which the pipeline or any part thereof is located, to enforce such obligation or to impose any penalty provided therefor, or the Secretary may, by proceeding as provided in this section, suspend or terminate the said grant of right-of-way for noncompliance with the provisions of this section.

(f) Any domestically produced crude oil transported by pipeline over rights-of-way granted pursuant to Section 28 of the Mineral Leasing Act of 1920, except such crude oil which is either exchanged in similar quantity for convenience or increased efficiency of transportation with persons or the government of an adjacent foreign state, or which is temporarily exported for convenience or increased efficiency of transportation across parts of an adjacent foreign state and reenters the United States, shall be subject to all of the limitations and licensing requirements of the Export Administration Act of 1969 (Act of December 30, 1969; 83 Stat 841) and, in addition, before any crude oil subject to this section may be exported under the limitations and licensing requirements and penalty and enforcement provisions of the Export Administration Act of 1969, the President must make and publish an express finding that such exports will not diminish the total quantity or quality of petroleum available to the United States, and are in the national interest and are in accord with the provisions of the Export Administration Act of 1969.

6. Range improvements such as fencing or reservoirs, etc. within the right-of-way area will not be disturbed, or where disturbance is necessary, they will be left in the original or better condition as is determined by the District Manager, Bureau of Land Management.

7. Before cutting through any fence on public land, the grantee will brace the fence firmly on both sides of the cut, and after completion of construction will (1) install a gate and/or cattle guard in the fence, or (2) replace a standard type fence across the right-of-way, as directed by the District Manager, Bureau of Land Management.

8. The grantee will construct waterbreaks on all disturbed slopes in accordance with the attached typical plan for waterbreak construction. General guidelines for installation of waterbreaks are: less than 2% grade, 200' interval; 2-4% grade, 100' interval; 4-5% grade, 75' interval; greater than 5% grade, 50' interval. A certain degree of latitude is allowed in the waterbreak interval spacing. Unstable soils may require a closer interval spacing, whereas the interval spacing may be greater on very stable soils or rock outcroppings. A conservative (close) interval spacing is the general recommendation. A channel grade of .002 is recommended from the waterbreak to the natural ground elevation. The waterbreaks should be constructed so that they drain freely to the natural ground elevation.

9. The grantee will effect a minimum of vegetative or soil disturbance consistent with practical construction operations and will smooth all disturbed areas to conform as nearly as practical with the adjacent terrain, provide adequate water drainage for any roads constructed to minimize erosion and maintain any service roads in good condition for use by automotive vehicles and permit the free use of any such service roads by employees of the Federal government or their authorized agents. The grantee will correct any deficiencies as determined to be necessary by the District Manager, Bureau of Land Management.

10. Proper precaution will be taken at all times to prevent and suppress fires. The grantee will be held responsible for suppression costs for any fires on public lands caused through negligence of his employees, contractors or subcontractors. No debris burning will be allowed without specific permission from the District Manager, Bureau of Land Management, in charge of administration of the natural resource lands involved.

11. In the event it is necessary to remove timber from the right-of-way lands, all merchantable timber will be purchased by the grantee at the total appraised price that is determined by the District Manager, Bureau of Land Management.

12. All disturbed areas are to be seeded with the seed mixture listed below. The seed is to have a germination of 90%. The seeding is to be done by drilling with a drill equipped with a depth regulatory to insure even depth of planting not to exceed ½ inch. Seeding is to be done during the months of September or October following construction completion. This seeding will be repeated until a satisfactory stand, as determined by the District Manager or his delegates, is obtained. The District Manager of the Bureau of Land Management is to be notified 15 days prior to seeding in order that arrangements can be made for supervision of the seeding project.

Seed mixture:

13. Proof of construction will be filed after completion of construction, but not until all rehabilitation work is complete and the grantee's own inspection shows that reseeded vegetation has been established satisfactorily. A period of 5 years from the date of approval of the right-of-way is usually allowed for construction.

(Date) (Name)

(Title)

WY 2800-22 (May 1977)
Page 3 of 3

Case Serial No.______________________

PRACTICES TO BE FOLLOWED
DURING GEOPHYSICAL EXPLORATION
OPERATIONS ON NATIONAL RESOURCE
LANDS IN WYOMING

____

Name, Address, and Telephone Number of Company Filing the Notice of Intent

____

Seismic Company Party Chief, Name and Telephone Number

____

Sub-Contracting Company

1. The operator will furnish a map with the "Notice of Intent" showing approximate line to be used. A map shall also be filed with the "Notice of Completion" showing the completed line. The map should be of a minimum scale of 1/2 inch equals one mile.

2. No blading or other dirt work will be allowed without written permission from the District Manager.

3. All disturbed areas will be reseeded as directed by the District Manager. Adequate vegetative cover will be established. Adequate cover will be determined through soil testing, vegetative density guides, etc.

4. Rehabilitation of disturbed areas is to be done concurrent with the geophysical operations inso far as possible. Seeding shall be done during the months of September or October. Although chances of failure are much greater with spring seeding, it may be done during April or May if approved by the District Manager.

5. No trees will be removed or damaged without specific approval from the District Manager. All merchantable timber shall be purchased by the operator at the total appraised price that is determined by the BLM.

6. Blasting or vibrating within one-eighth (1/8) mile of Federally owned or controlled springs and flowing water wells must be approved in writing by the District Manager.

7. No blasting or dozing will be permitted within one-quarter (1/4) mile of historic trails, natural areas, identified archeological sites, and recreation areas.

8. The operator shall avoid any operations when the ground is muddy and/or wet. The District Manager may prohibit exploration, drilling, or other activities during wet or heavy snow periods.

9. Water for drilling purposes will not be obtained from Federally owned or controlled water sources such as reservoirs and springs unless specific permission is obtained from the District Manager.

10. Report any available information concerning water sands or artesian flows to the District Office.

11. Plugging of drill holes will conform to the Wyoming Abandoned Drill Holes Act (Sec.30-96.14 et. Seq., W.S. 1957, C. 1967 as amended). Drill hole cuttings will be scattered so that the pile is less than 6 inches in height. (See sample drawings 49-94-3045-1 & 2.)

12. Powder magazines will be located out of sight of and at least 1/4 mile from traveled roads. Loaded shot holes will not be left unattended.

13. All trash, flagging, lath, etc. will be removed and hauled to an authorized disposal site. No oil or lubricants shall be drained onto the ground surface.

14. The operator must notify the District Manager the date rehabilitation operations commence and are completed.

15. Whenever possible, a portable mud pit shall be used when drilling with fluids.

16. A copy of these practices to be followed will be kept by each seismic crew.

I have been appraised of the practices which should be followed or avoided in the conduct of our geophysical operations. These practices will be explained to all of our subcontractors and they also will be expected to meet all the requirements.

Signature of Party Chief	Date

Additional Surface Protection Requirements

WSO 3045-1 (Mar 1976)

Oil and Gas Lease Stipulations
(to deal with specific situations)

1. All of the land in this lease is included in (recreation or special area, etc.). Therefore, no occupancy or disturbance of the surface of the land described in this lease is authorized. The lessee, however, may exploit the oil and gas resources in this lease by directional drilling from sites outside this lease. If a proposed drilling site lies on land administered by the Bureau of Land Management, a permit for use of the site must be obtained from the BLM District Manager before drilling or other development begins.

2. No access or work trail or road, earth cut or fill, structure or other improvement, other than an active drilling rig, will be permitted if it can be viewed from the (road, lake, river, etc.).

3. No occupancy or other activity on the surface of (legal subdivision) is allowed under this lease.

4. No occupancy or other surface disturbance will be allowed within ___________ feet of the _______________________(road, trail, river, creek, canal, etc.). This distance may be modified when specifically approved in writing by the District Engineer, Geological Survey, with the concurrence of the District Manager, Bureau of Land Management.

5. No drilling or storage facilities will be allowed within _____ feet of (live water, the reservoir, etc.) located in (legal subdivision). This distance may be modified when specifically approved in writing by the District Engineer, Geological Survey, with the concurrence of the District Manager, Bureau of Land Management.

6. No occupancy or other surface disturbance will be allowed on slopes in excess of _____ percent, without written permission from the District Engineer, Geological Survey, with the concurrence of the District Manager, Bureau of Land Management.

7. In order to (minimize watershed damage, protect important seasonal wildlife habitat, etc.) exploration, drilling, and other development activity will be allowed only during the period from _______________ to _________________. This limitation does not apply to maintenance and operation of producing wells. Exceptions to this limitation in any year may be specifically authorized in writing by the District Engineer, Geological Survey, with the concurrence of the District Manager, Bureau of Land Management.

8. In order to minimize watershed damage during muddy and/or wet period the District Manager, Bureau of Land Management, through the District Engineer, Geological Survey, may prohibit exploration, drilling or other development. This limitation does not apply to maintenance and operation of producing wells.

9. The __________________ (trail/road) will not be used as an access road for activities on this lease.

10. To maintain esthetic values, all semi-permanent and permanent facilities may require painting or camouflage to blend with the natural surroundings. The paint selection or method of camouflage will be subject to approval by the District Engineer, Geological Survey, with the concurrence of the District Manager, Bureau of Land Management.

Appendix 3

Plant and Animal Lists

Appendix 3

Plant List

The following are the more important plants present in varying abundance. This is not a complete list of species present.

Grasses

Agropyron smithii	western wheatgrass
Agropyron spicatum	bluebunch wheatgrass
Aristida longiseta	red three-awn
Bouteloua gracilis	blue grama
Bromus tectorum	cheatgrass brome
Calamovilfa longifolia	prairie sandreed
Elymus canadensis	Canadian wildrye
Festuca octoflora	sixweeks fescue
Festuca idahoensis	Idaho fescue
Hordeum jubatum	foxtail barley
Koeleria cristata	prairie junegrass
Oryzopsis hymenoides	Indian ricegrass
Poa secunda	Sandberg's bluegrass
Sitanion hystrix	squirreltail
Sporobolus airoides	alkali sacaton
Stipa spp.	needle grasses

Sedges

Carex geyeri	elk sedge
Carex filifolia	threadleaf sedge

Forbs

Achillea lanulosa	western yarrow
Castilleja angustifolia	Indian paintbrush
Cirsium arvense	Canadian thistle
Delphinium spp.	larkspurs
Eriogonum spp.	buckwheats
Halogeton glomeratus	halogeton
Iris missouriensis	rocky mountain iris
Lepidium spp.	pepperweeds
Lypinus spp.	lupines
Penstemon spp.	penstemons
Phlox spp.	phlox
Salsola kalitenuifolia	Russian thistle
Sphaeralcea spp.	globemallows
Taraxacum officinale	dandelion
Xanthium spp.	cocklebur
Zigadenus spp.	death camas
Rumex crispus	curly dock
Opuntia polycantha	plains pickly pear cactus

Shrubs

Amelanchier spp.	serviceberry
Artemisia nova	black sagebrush
Artemisia tridentata	big sagebrush
Artemisia spinescens	bud sagebrush
Atriplex nuttallii	Nuttalls saltbush
Atriplex confertifolia	shadscale
Chrysothamnus spp.	rabbitbrush
Eurotia lanata	winterfat
Gutierrezia sarothrae	broom snakeweed
Purshia tridentata	bitterbrush
Rosa spp.	wildrose
Sarcobatus vermiculatus	black greasewood

Trees

Abies lasiocarpa	subalpine fir
Cornus servicea	red osier dogwood
Juniperus spp.	juniper
Pinus contorta	lodgepole pine
Pinus flexilis	limber pine
Populus spp.	cottonwoods
Populus tremuloides	quaking aspen
Picea engelmanni	Englemann's spruce
Pseudotsuga menziesii	Douglas fir
Salix spp.	willow

Assumptions and Estimates Used in Wildlife Impact Analysis

Estimated — 55,000 acres in known geologic structures
Estimated — 1,200,000 acres subject to exploration outside KGS

Estimated potential acreage loss of existing rangeland plant communities:

	Annual Avg.	10 Yrs.
Preliminary Exploration (Seismic lines, strat. drilling, etc.)	325 acres	3,250 acres
Wildcat Drilling	25 acres	250 acres
Subtotal	350 acres	3,500 acres
It is estimated 50% of disturbed acreage which is subject to rehabilitation will have been rehabilitated to previous or comparable condition during next ten years. (Subtract):	175 acres	1,750 acres
Unrecovered	175 acres	1,750 acres
Production and Development (well sites, facilities, roads, etc. permanently occupying sites during study period)	150 acres	1,500 acres
Acreage with original native plant community lost or severely depleted	325 acres	3,250 acres

It is estimated that four times (4) the acreage lost to permanent facilities, roads, etc., will be rendered unsuitable to a high degree, if not totally, as habitat for big game, predators, nesting game birds, and waterfowl and certain other species due to field operations and human activities. This is in addition to the actual acreage occupied by these facilities.

	Annual Avg.	**10 Yrs.**
	150 acres	1,500 acres
	x 4	x 4
	600 acres	6,000 acres
Plant community acreage physically lost or severely depleted (wildlife habitat lost for numerous species)	325 acres	3,250 acres
	925 acres	9,250 acres
Estimated acreage of land which can be expected to cease to provide usable habitat for the existing wildlife numbers and/or species compliment	925 acres	9,250 acres

A listing of all fishes, amphibians, reptiles, birds, and mammals was prepared by a literature search. The literature used was as follows:

Fishes	(Baxter and Simon, 1970).
Amphibians and Reptiles	(Wyoming Game and Fish Dept., 1974b).
Birds	(Wyoming Game and Fish Dept., 1977; Peterson, 1961; Robbins, Bruun, and Zim, 1966).
Mammals	(Wyoming Game and Fish Dept., 1974a; Burt and Grossenheider, 1964).

All species lists are not specific to the Grass Creek Planning Unit, but are Big Horn Basin wide. The bird list has a description of preferred habitat taken from the literature and also a description of the habitat the species occupy in the Big Horn Basin. This second description is completed only if the species has been identified in the Basin by qualified personnel.

REPTILES	HABITAT
Squamata	
Iguanidae	
Sagebrush Lizard *Sceloporus graciosus*	Scatter low brush area
Eastern Short Horned Lizard — horney toad *Phrynosoma douglassi brevirostre*	Usually loose soil
Viperidae	
Prairie Rattlesnake *Crotalus viridis viridis*	Semi-arid, rocky, below 7,000' areas
Boidae	
Rocky Mountain Rubber Boa *Charina bottae utahensis*	Forests and woodlands, moist soil
Colubridae	
Eastern Yellow Bellied Racer *Coluber constrictor flaviventris*	Below 7,000'
Bullsnake *Pituophis melanoleucas sayi*	Associated with rodent populations
Pale Milksnake *Lampropeltis triangulum multistrata*	Woody hills regions
Wandering Garter Snake *Thamnophis elegans vagrans*	Variety of habitats, often aquatic
Western Plains Garter Snake *Thamnophis radix haydeni*	Aquatic habitats
Red Sided Garter Snake *Thamnophis sirtalis parietalis*	Aquatic habitats
Chelonia	
Chelydridae	
Snapping Turtle *Chelydra serpentina*	Warm water lakes, slow rivers
Trionychidae	
Western Spiney Softshell *Trionyx spiniferus hartwegi*	Ponds and slow rivers
Testudinidae	
Painted Turtle *Chrysemys picta*	Ponds, marshes, sloughs

AMPHIBIANS	HABITAT
Urodela	
Ambystomidae	
Tiger Salamander — blotched *Ambystom tigrinum melanostictum*	Around water
Anura	
Pelobatidae	
Plains Spadefoot *Scaphiopus bombifrons*	Plains, hills, riverbottoms
Bufonidae	
Great Plains Tod *Bufo cognatus*	Prairie or desert
Hylidae	
Boreal Chorus Frog *Pseudacris triseriata maculata*	Grassy pools, lakes
Ranidae	
Leopard Frog *Rana pipiens*	Permanent waters

NON-GAME MAMMALS	HABITAT
Chiroptera	
Little Brown Myotis *Myotis lucifugus*	Timbered areas
Small-footed Myotis *Myotis subalatus*	Lower elevations
Long-legged Myotis *Myotis volans*	Unknown
Long-eared Myotis *Myotis evotis*	Woodlands & semi-desert
Silver-haired Bat *Lasionycteris noctivagens*	Transition & Canadian life zones
Hoary Bat *Lasiurus cinereus*	Unknown — migratory
Townsend's Big-eared Bat *Plecotus townsendii*	Arid areas — cave dweller
Spotted Bat *Euderma maculatum*	Rare — Big Horn Basin only
Big Brown Bat *Eptesicus fuscus*	Cave dweller
Insectivora	
Masked Shrew *Sorex cinereus*	Montana habitat
Vagrant Shrew *Sorex vagrans*	Lacking in arid areas
Dwarf Shrew *Sorex nanus*	High elevations
Water Shrew *Sorex palustris*	Near streams, 5,400-10,600' elev.
Merriam's Shrew *Sorex merriami*	Arid areas
Lagomorpha	
Pika *Ochotona princeps*	Mountain — rock piles
Rodentia	
Sciuridae	
Least Chipmunk *Eutamias minimus*	Ubiquitous
Uinta Chipmunk *Eutamias umbrinus*	Unknown
Marmot *Marmota flaviventris*	Rocky, mountainous areas
Richardson's Ground Squirrel *Spermophilus richardsonii*	Grasslands
Uinta Ground Squirrel *Spermophilus armatus*	Moist meadows & brush near water
Golden-mantled Ground Squirrel *Spermophilus lateralis*	Rocky places in forests and open pine woods
White-tailed Prairie Dog *Cynomys leucurus*	Desert grassland
Northern Flying Squirrel *Glaucomys sabrinus*	Forest
Geomyidae	
Northern Pocket Gopher *Thomomys talpiodes*	Ubiquitous
Heteromyidae	
Wyoming Pocket Mouse *Perognathus fasciatus*	Arid areas
Ord's Kangaroo Rat *Dipodomys ordii*	Arid areas
Cricetidae	
Western Harvest Mouse *Reithrodontomys megalotis*	Prairie areas

NON-GAME MAMMALS	HABITAT
Deer Mouse *Peromyscus maniculatus*	Ubiquitous
Northern Grasshopper Mouse *Onychomys leucogaster*	Arid areas
Bushy-tailed Woodrat *Neotoma cinerea*	Rocky areas
Grappers Red Backed Vole *Clethrionomys gapperi*	Montane & riparian
Meadow Vole *Microtus pennsylvanicus*	Moist areas
Montana Vole *Microtus montanus*	Mountainous areas
Long-tailed Vole *Microtus longicaudus*	Montane areas & riparian habitat
Prairie Vole *Microtus ochrogaster*	Prairie areas
Sagebrush Vole *Lagurus curtatus*	Sagebrush arid areas
Richardson's Vole *Microtus richardsoni*	Montane
Zapodidae	
Meadow Jumping Mouse *Zapus hubsonius*	Low meadows
Western Jumping Mouse *Zapus princeps*	Montane areas

GAME ANIMALS AND FURBEARERS	HABITAT
Carnivora	
Ursidae	
Black Bear *Ursus americanus*	Mountainous areas
Procyonidae	
Raccoon *Procyon lotor*	Riparian
Mustelidae	
Marten *Martes americana*	Spruce fir forest
Short-tail Weasel *Mustela erminea*	Brushy areas
Long-tail Weasel *Mustela frenata*	Near water
Mink *Mustela vison*	Riparian
Black-footed Ferret *Mustela nigripes*	Prairie dog towns
River Otter *Lutra canadensis*	Riparian
Badger *Taxidea taxus*	Grasslands & desert
Spotted Skunk *Spilogale putorius*	Brushy areas — rock desert
Striped Skunk *Mephitis mephitis*	Widespread
Canidae	
Coyote *Canis latrans*	Ubiquitous
Grey Wolf *Canis lupus* (possibly *irremotus*)	Forests, woodlands
Red Fox *Vulpes vulpes*	Lower elevations — widespread
Felidae	
Mountain Lion *Felis concolor*	Woodland and Forest
Lynx *Lynx canadensis*	Forest
Bobcat *Lynx rufus*	Rimrock areas
Rodentia	
Sciuridae	
Red Squirrel *Tamiasciurus hudsonicus*	Coniferous forest
Castoridae	
Beaver *Castor canadensis*	Riparian
Cricetidae	
Muskrat *Ondatra zibethicus*	Riparian
Erethizontidae	
Porcupine *Erethizon dorsatum*	Usually forests
Lagomorpha	
Leporidae	
Whitetail Jackrabbit *Lepus townsendi*	Grassland, desert
Snowshoe Hare *Lepus americanus*	Mountains
Desert Cottontail *Sylvilagus auduboni*	Woodlands, desert
Mountain Cottontail *Sylvilagus nuttalli*	Higher elevations

GAME ANIMALS AND FURBEARERS	HABITAT
Artiodactyla	
Cervidae	
Elk *Curvus canadensis*	Mountains — foothills
Mule deer *Odocoileus hemionus*	Ubiquitous
Whitetail deer *Odocoileus virginianus*	Low elevation, riparian
Moose *Alces alces*	Forests, riparian
Antilocapridae	
Pronghorn *Antilocapra americana*	Plains, desert, foothills
Bovidae	
Bighorn Sheep *Ovis canadensis*	High elevations — mountains — canyons

LIVESTOCK	HABITAT
Artiodactyla	
Bovidae	
Domestic Sheep *Ovis aries*	Rangeland
Domestic Cattle *Bos taurus*	Rangeland
Perissodactyla	
Equidae	
Domestic and Ferral Horse *Equus caballus*	Feral horses restricted to arid areas

FISHES	HABITAT
Acipenseriformes	
Acipenseridae	
Shovelnose sturgeon *Scaphirhynchus platorynchus*	Rare in Wyo.; unconfirmed in Big Horn & Greybull Rivers
Clupeiformes	
Hiodontidae	
Goldeye *Hiodon alosoides*	Formerly in Big Horn River
Salmonidae	
Mountain Whitefish *Prosopium williamsoni*	Mountain Big Horn tributaries
Cutthroat Trout *Salmo clarki*	Mountain streams
Rainbow trout *Salmo gairdneri*	Introduced — mountain streams, Big Horn River
Brown trout *Salmo trutta*	Introduced — mountain streams, Big Horn River
Brook trout *Salvelinus fontinalis*	Introduced — mountain streams
Cypriniformes	
Cyprinidae	
Carp *Cyprinus carpio*	Lowland waters
Goldenshiner *Notemigonus crysoleucas*	Introduced — Big Horn River
Creek Chub *Semotilus atromaculatus*	Big Horn River — lowland streams
Lake Chub *Couesius plumbeus*	Big Horn River
Flathead Chub *Hybopsis gracilis*	Big Horn River
Sturgeon Chub *Hybopsis gelida*	Rare in Wyo., Big Horn River
Longnose Dace *Rhinichthys cataractae*	Riffles in small & large streams
Plains Minnow *Hybognathus placitus*	Small silty streams
Silvery Minnow *Hybognathus nuchalis*	Big Horn River
Flathead Minnow *Pimephales promelas*	Slow moving weedy streams
Catostomidae	
River Carpsucker *Carpiodes carpio*	Big Horn River
Northern Redhorse *Moxostoma macrolepidotum*	Big Horn River
White Sucker *Catostomus commersoni*	Nearly any waters
Longnose Sucker *Catostomus catostomus*	Nearly any waters
Mountain Sucker *Catostomus platyrhynchus*	Nearly any waters

FISHES	HABITAT
Ictaluridae	
Black Bullhead *Ictalurus melas*	Big Horn River, Wardel Res.
Channel Catfish *Ictalurus punctatus*	Introduced — Big Horn River
Stonecat *Noturus flavus*	Big Horn River
Gadiformes	
Gadidae	
Burbot *Lota lota*	Big Horn River
Cyprinodontiformes	
Cyprinodontidae	
Plains killifish *Fundulus kansae*	Big Horn River; lowland tributaries
Perciformes	
Centrarchidae	
Green Sunfish *Lepomis cyanellus*	Introduced — Big Horn River
Pumpkinseed *Lepomis gibbosus*	Introduced — Big Horn River
Percidae	
Sauger *Stizostedion canadense*	Big Horn River
Walleye *Stizostedion vitreum*	Big Horn River — Wardel Res.

Birds	**Literature Habitat**	**Planning Unit Habitat**
Common Loon *Gavia immer* — B	Lakes and rivers	
Eared Grebe *Podiceps caspicus* — B	Shallow lakes	Farm ponds Stock reservoirs
Western Grebe *Aechmophorus occidentalis* — B	Lakes	Large open water reservoirs
Pied-Billed Grebe *Podilymbus podiceps* — B	Shallow water	
White Pelican *Pelecanus erythrorhynchos* — B	Lakes	
Double Crested Cormorant *Phalacrocorax auritus* — B	Lakes and rivers	
Great Blue Heron *Ardea herodias* — B	Shallow water	Large reservoirs Wardel — Big Horn River
Green Heron *Butorides virescens* — B	Small ponds & streams	
Black Crowned Night Heron *Nycticorax nycticorax* — B	Marshes	
Common Egret *Cosmerodius albus* — P	Marshes	
Snowy Egret *Leucophoyx thula* — P	Marshes	
Lease Bittern *Ixobrychus exilis* — P	Tall fresh water grasses & sedges	
American Bittern *Betaurus lentiginosus* — B	Marshes	
Wood Ibis *Mycteria americana* — P	Marshes and ponds	
White-Faced Ibis *Plegadis chihi* — B	Marshes	
Whooping Crane *Grus americana* — P	Bogs	

B — Breeding W — Wintering
M — Migratory P — Possible

Birds	Literature Habitat	Planning Unit Habitat
Canada Goose *Brunta canadensis* — B	Lake shores	Big Horn River; Wardel Res.
Black Brant *Branta nigricans* — P	Lakes and marshes	
White-Fronted Goose *Anser albifrons* — M	Lakes and marshes	
Snow Goose *Chen hyperborea* — M	Lakes and marshes	
Mallard *Anas platyrhynchos* — BMW	Ponds and marshes	Most permanent water
Gadwall *Anas strepera* — BM	Ponds	Most permanent water
Pintail *Anas acuta* — B	Lakes and ponds	Larger open waters
Green-Winged Teal *Anas carolinensis* — B-W	Small ponds	Most permanent water
Blue-Winged Teal *Anas discors* — B	Ponds and marshes	Most permanent water
Cinnamon Teal *Anas cyanoptera* — B	Ponds and marshes	Some permanent water, less common than other teal
American Widgeon *Mareca americana* — R	Ponds and marshes	Most permanent waters
Shoveler *Spatula clypeata* — B	Ponds and marshes	Some permanent waters
Redhead *Authya americana* — B	Ponds and lakes	
Ring-Necked Duck *Aythya collaris* — M	Ponds	
Canvasback *Aythya valisneria* — B	Ponds and lakes	
Greater Scaup *Aythya marila* — M	Lakes and ponds	
Lesser Scaup *Aythya affinis* — B	Lakes and ponds	
Barrow's Goldeneye *Bucephala islandica* — B-W	Lakes and ponds	
Bufflehead *Bucephala albeola* — M	Lakes and ponds	Winters on Big Horn River
Oldsquaw *Clangula hyemalis* — P	Lakes and ponds	
Harlequin Duck *Histrionicus histrionicus* — B	Rivers	
Ruddy Duck *Oxyura jamaicensis* — B	Lakes and ponds	Most permanent water
Hooded Merganser *Lophodytes cucullatus* — B	Wooded lakes and streams	
Common Merganser *Mergus merganser* — B-W	Ponds and streams	
Red-Breasted Merganser *Mergus serrator* — M	Ponds and streams	
Turkey Vulture *Cathartes aura* — B	Fields and roadsides	Most of Basin

B — Breeding W — Wintering
M — Migratory P — Possible

Birds	Literature Habitat	Planning Unit Habitat
Goshawk *Accipiter gentalis* — W	Forests	
Sharp-Shinned Hawk *Accipiter striatus* — B	Open woodlands	
Cooper's Hawk *Accipiter cooperii* — B	Open woodlands	
Red-Tailed Hawk *Buteo jamaicensis* — B-W	Woodlands and open country	Foothills
Harlan's Hawk *Buteo harlani* — M	Open country	
Swainson's Hawk *Buteo swainsoni* — B	Open country	Sage type & farmland
Rough-Legged Hawk *Buteo lagopus* — W	Open country	Winters in large numbers in lowland sage type
Ferruginous Hawk *Buteo regalis* — B	Open country	Low elevations Badlands
Golden Eagle *Aquila chrysaetos* — B-W	Remote mountains & deserts	Most of Basin; winters in large numbers
Bald Eagle *Haliaeetus leucocephalas* — B-W	Near water	Usually near larger streams
Marsh Hawk *Circus cyaneus* — B-W	Grasslands and marshes	Most of Basin
Osprey *Pandion haliaetus* — B-M	Near water	
Prairie Falcon *Falco mexicanus* — B	Plains	Observations at sec. 13, T. 46 N., R. 100 W., and sec. 34, T. 50 N., R. 97 W.
Peregrine Falcon *Falco peregrinus* — M	Mountains	
Pigeon Hawk *Falco columbarius* — M	Open country	
Sparrow Hawk *Falco sparverius* — B-M	Open country	Most of Basin; migrate in large numbers
Blue Grouse *Dendrajaipus obscurys* — B-W	Forests	Coniferous forest & adjacent sage-brush
Spruce Grouse *Canachites canadensis* — P	Forests	
Ruffed Grouse *Bonasa umbellus* — B-W	Forests	Coniferous forests, usually around aspen
Sharp-Tailed Grouse *Pedioecetes phosianellus* — P	Prairies	
Sage Grouse *Centrocercus urophasianus* — B-W	Sagebrush	Sagebrush community
Bobwhite *Colinus virginianus* — B-W	Brushlands	
Ring-Necked Pheasant *Phasianus colchicus* — B-W	Farmlands	Around agriculture
Chukar *Alectoris graeca* — B-W	Rocky, barren lands	Most of Basin up to treeline
Gray Partridge *Perdix perdix* — B-W	Farmland	Most of Basin up to treeline

B — Breeding W — Wintering
M — Migratory P — Possible

Birds	Literature Habitat	Planning Unit Habitat
Turkey *Melelagris gallopavo* — B-W	Woodlands	Riparian habitat
Sandhill Crane *Grus canadensis* — B	Prairies and fields	
Virginia Rail *Rallus limicola* — B	Marshes	
Sora *Porzana carolina* — B	Marshes	
Yellow Rail *Coturnicops noveboracensis* — M	Marshes	
American Coot *Fulica americana* — B	Ponds	Larger reservoirs
Semi-palmated Plover *Charadrius semipalmatus* — M	Beaches and mudflats	
Snowy Plover *Charadrius alexandrinus* — MP	Alkali ponds	
Killdeer *Charadrius vociferus* — B	Fields and pastures	Wetlands, marshes Wet meadows
Mountain Plover *Eupoda montana* — B	Short grass prairie	Wet areas
American Golden Plover *Pluvaialis dominica* — M	Fields and pastures	
Black-Bellied Plover *Squatarola squatarola* — M	Mudflats	
Common Snipe *Capella gallinago* — B	Marshes and river banks	
Long-Billed Curlew *Numenius americanus* — B	Meadows and pastures	
Upland Plover *Bartramia longicauda* — B	Grassland	
Spotted Sandpiper *Actitis macularia* — B	Near Water	Some reservoirs
Solitary Sandpiper *Tringa solitaria* — M	Streams and lakes	Some reservoirs
Willett *Catoptrophorus semipalmatus* — B	Lakes	
Greater Yellowlegs *Totanus melanoleucus* — M	Marshes	
Lesser Yellowlegs *Totanus flavipes* — M	Marshes	
Pectoral Sandpiper *Eyolia melanotos* — M	Marshes and fields	
White-Rumped Sandpiper *Erolia fuscicollis* — M	Marshes	
Baird's Sandpiper *Erolia bairdii* — M	Marshes	Some reservoirs in spring
Least Sandpiper *Erolia minutilla* — M	Muddy shorelines	
Dunlin *Erolia alpina* — M	Shorelines	
Short-Billed Dowitcher *Limnodromus griseus* — M	Shorelines	

B — Breeding W — Wintering
M — Migratory P — Possible

Birds	Literature Habitat	Planning Unit Habitat
Long-Billed Dowitcher *Limnodromus scolopaceus* — M	Shorelines	
Stilt Sandpiper *Micropalama himantopus* — M	Marshes	
Semi-palmated Sandpiper *Ereunetes pusillus* — M	Shorelines	
Western Sandpiper *Ereunetes mauri* — M	Mudflats	
Buff-Breasted Sandpiper *Tryngites subruficollis* — M	Short grass	
Marbled Godwit *Limosa fedoa* — M	Prairies and meadows	
Hudsonian Godwit *Limosa haemastica* — M	Marshes and meadows	
Sanderling *Crocethia alba* — M	Sandy beaches	
American Avocet *Recurvirostra americana* — B	Marshes and shorelines	
Black-Necked Stilt *Himantopus mexicanus* — P	Shorelines	
Wilson's Phalarope *Steganopus tricolor* — M	Prairie ponds	Around some reservoirs
Northern Phalarope *Lobipes lobatus* — M	Shorelines	
Herring Gull *Larus argentatus* — M	Harbors and garbage dumps	
California Gull *Larus californicus* — M	Shorelines	Large reservoirs
Ring-Billed Gull *Larus delawarensis* — B	Shorelines	Large reservoirs
Mew Gull *Larus canus* — P	Shorelines	
Franklin's Gull *Larus pipixcan* — M	Shorelines	
Bonaparte's Gull *Larus philadelphia* — M	Shorelines	
Black Legged Kittiwake *Rissa tridactyla* — P	Shorelines	
Forester's Tern *Sterna forsteri* — B	Marshes	
Caspian Tern *Hydroprogne caspia* — B	Shorelines	
Black Tern *Chlidonias niger* — B	Marshes	
Rock Dove *Columba livia* — B-W	Farmyards	Agricultural areas
Mourning Dove *Zenaidura macroura* — B	Farmlands	Most of Basin
Yellow-Billed Cuckoo *Coccyzus americanus* — B	Forests and brushlands	
Black-Billed Cuckoo *Coccyzus erythropthalmus* — B	Forests and brushlands	

B — Breeding W — Wintering
M — Migratory P — Possible

Birds	Literature Habitat	Planning Unit Habitat
Screech Owl *Otusasio* — B-W	Woodlands	
Great-Horned Owl *Bubo virgianus* — B-W	Woodlands	Limber pine-juniper and riparian
Pygmy Owl *Glaucidium gnoma* — B-W	Forests	
Burrowing Owl *Speotyto cunicularia* — B	Prairie dog towns	Five observed — sec. 21, T.47 N., R. 94 W.
Barred Owl *Stix varia* — B-W	River bottoms	
Great Gray Owl *Strix nebulosa* — P	Coniferous forest	
Long-Eared Owl *Asio otus* — B-W	Forests	
Short-Eared Owl *Asio flammeus* — B-W	Plains and marshes	
Saw-Whet Owl *Aegolius acadicus* — B-W	Coniferous forest	
Poor-Will *Phalaenoptilus nuttalli* — B	Seen at dusk	
Common Nighthawk *Chordeiles minor* — B	Around trees and houses	Agricultural areas and foothills
Chimney Swift *Chaetura pelagica* — P	Fly nearly continuously during day	
White-Throated Swift *Aeronautes saxatlis* — B	Around cliffs and canyons	Near water and cliffs
Black-Chinned Hummingbird *Archilochus alexandri* — B	Mountains	
Broad-Tailed Hummingbird *Selasphorus platycercus* — B	Mountains	
Rufous Hummingbird *Selasphorus rufus* — M	Mountains	
Belted Kingfisher *Megaceryle alcyon* — B	Around water	Around water which supports fish
Yellow-Shafted Flicker *Colaptes auratus* — P-B	Open country around trees	
Red-Shafted Flicker *Colaptes cafer* — B	Around trees	Around deciduous trees & limber pine; migrates in fall in large numbers
Red-Headed Woodpecker *Melanerpes erythrocephalas* — B	Open deciduous woods	
Lewis' Woodpecker *Asyndesmus lewis* — B	Large trees in open country	
Yellow-Bellied Sapsucker *Sphyrapicus varius* — B	Woods and orchards	
Williamson's Sapsucker *Sphyrapicus thyroideus* — B	Pine forests	
Hairy Woodpecker *Dendrocopos villosus* — B-W	Deciduous or mixed forest	
Downy Woodpecker *Dendrocopos pubescens* — B-W	Around trees	Coniferous forest
Black-Backed Three-Toed Woodpecker *Picoides arcticus* — B-W	Coniferous forest	

B — Breeding W — Wintering
M — Migratory P — Possible

Birds	Literature Habitat	Planning Unit Habitat
Northern Three-Toed Woodpecker *Picoides tridactylus* — B-W	Coniferous forest	
Eastern Kingbird *Tyrannus tyrannus* — B	Semi-open country	Around trees
Western Kingbird *Tyrannus verticalis* — B	Around farms and streams	
Cassin's Kingbird *Tyrannus vociferans* — B	Woodland or brushy areas	
Eastern Phoebe *Sayornis phoebe* — M	Around farm buildings and bridges	
Say's Phoebe *Sayornis saya* — B	Buildings, bluffs and cliffs	
Traill's Flycatcher *Empidonax traillii* — B	Woodlands	
Least Flycatcher *Empidonax minimus* — B	Woodlands	
Dusky Flycatcher *Empidonax oberholseri* — B	Woodlands	
Western Flycatcher *Empidonax difficilis* — B	Coniferous forest	
Western Wood Pewee *Contopus sordidulus* — B	Forests	
Olive-Sided Flycatcher *Nuttallornis borealis* — M	Coniferous forest	
Horned Lark *Eremophila alpestris* — B-W	Open country	Very common in rangelands
Violet-Green Swallow *Tachycineta thalassina* — B	Mountains or towns	Cliffs or bridges usually around water
Tree Swallow *Iridoprocne bicolor* — B	Nests in trees near water	
Bank Swallow *Riparia riparia* — B	Steep river banks	
Rough-Winged Swallow *Stelgidopteryx ruficollis* — B	Around water	
Barn Swallow *Hirundo rustica* — B	Around cliffs, bridges or buildings	Around cliffs or large structures
Cliff Swallow *Petrochelidon pyrrhonota* — B	Around cliffs or bridges	Around cliffs
Purple Martin *Progne subis* — B	Around towns	
Gray Jay *Perisoreus canadensis* — B-W	Coniferous forest	Coniferous forest
Blue Jay *Cyanoctta cristata* — B-W	Pine woods	
Steller's Jay *Cyanoctta stelleri* — B-W	Coniferous forest	
Black-Billed Magpie *Pica pica* — B-W	Open country near trees	Most of Basin
Common Raven *Corvus corax* — B-W	Near timber	Higher altitudes
Common Crow *Corvus brachyrhynchos* — B-W	Near trees	Most of Basin; up to treeline

B — Breeding W — Wintering
M — Migratory P — Possible

Birds	Literature Habitat	Planning Unit Habitat
Pinnon Jay *Gymnorhinus cyanocephalus* — B-W	Juniper	Coniferous forest, especially limber pine-juniper
Clark's Nutcracker *Nucifraga columbiana* — B-W	Coniferous forest	Coniferous forest, especially ponderosa pine and Douglar-fir
Black-Capped Chickadee *Parus atricapillus* — B	Coniferous forest	
Mountain Chickadee *Parus gambeli* — B-W	Coniferous forest	Coniferous forest
White-Breasted Nuthatch *Sitta carolinensis* — B-W	Deciduous woodlands	Deciduous trees
Red-Breasted Nuthatch *Sitts canadensis* — W	Coniferous forest	Douglas-fir type in fall
Pygmy Nuthatch *Sitta pygmaea* — B-W	Pine forest	Coniferous forest
Brown Creeper *Erthia familiaris* — B-W	Woodlands	
Dipper *Cinclus mexicanus* — B-W	Mountain streams	Mountain streams
House Wren *Troglodytes aedon* — B	Shrubbery and brush	
Long-Billed Marsh Wren *Telmatodytes palustris* — B	Marshes	
Canyon Wren *Catherpes mexicanus* — B-W	Rocky barrens	
Rock Wren *Salpinctes obsoletus* — B	Rocky slopes	Rocky sage type
Catbird *Dumetta carolinensis* — B	Dense brush	Riparian brush
Brown Thrasher *Toxostoma rufum* — B	Brushy areas	
Sage Thrasher *Oreoscoptes montanus* — B	Heavy sage	
Robin *Turdus migritorius* — B-W	Towns and woodlands	Agricultural areas, riparian and forests
Varied Thrush *Ixoreus naevius* — P	Coniferous forest	
Hermit Thrush *Hylocichla guttata* — B	Woodlands	
Swainson's Thrush *Hylocichla ustulata* — B	Forest understory	
Gray-Cheeked Thrush *Hylocichla minima* — M	Forest understory	
Veery *Hylocichla fuscescens* — B	Deciduous forest	
Eastern Bluebird *Sialia sialis* — B	Roadsides and farmyards	
Western Bluebird *Sialia mexicana* — B	Roadsides and farmyards	
Mountain Bluebird *Sialia currucoides* — B-W	Higher elevations	Most of Basin in spring Higher elev. in summer

B — Breeding W — Wintering
M — Migratory P — Possible

Birds	Literature Habitat	Planning Unit Habitat
Townsend's Solitaire *Myadestes townsendi* — B-W	Coniferous forest	Ponderosa pine type uncommon
Golden-Crowned Kinglet *Regulus satrapa* — B-W	Woodland	
Ruby-Crowned Kinglet *Regulus calendula* — M	Coniferous forest	
Water Pipit *Anthus spinoletta* — B	Alpine meadows	
Sprague's Pipit *Anthus spragueii* — M	Grassland	
Bohemian Waxwing *Bombycilla garrulus* — W	Wander in large flocks	
Cedar Waxwing *Bombycilla cedrorum* — B	Berry-bearing trees and shrubs	
Northern Shrike *Lanius excubitor* — W	Grassland	
Loggerhead Shrike *Lanius ludovicianus* — B-W	Grassland	Lower Cottonwood Creek
Starling *Sturnus vulgaris* — B-W	Around farmyards	Agricultural areas
Solitary Vireo *Vireo solitarius* — B-M	Forests	
Red-Eyed Vireo *Vireo olivaceus* — B	Forests	
Warbling Vireo *Vireo gilvus* — B	Deciduous forests	
Black-and-White Warbler *Mniotilta varia* — M	Deciduous forests	
Tennessee Warbler *Vermivora peregrina* — M	Aspen and spruce	
Orange-Crowned Warbler *Vermivora celeta* — B	Low trees and brush	
Yellow Warbler *Dendroica petechia* — B	Willow thickets	Riparian brush
Magnolia Warbler *Dendroica magnolia* — P	Spruce forest	
Myrtle Warbler *Dendroica coronata* — M	Spruce forest	
Audubon's Warbler *Dendroica auduboni* — B	Forest	Coniferous forest
Townsend's Warbler *Dendroica townsendi* — P	Coniferous forest	
Black-Throated Green Warbler *Dendroica virens* — P	Coniferous forest	
Chestnut-Sided Warbler *Dendroica pensylvanica* — P	Brush	
Bay-Breasted Warbler *Dendroica castanea* — M	Coniferous forest	
Blackpoll Warbler *Dendroica striata* — M	Coniferous forest	
Palm Warbler *Dendroica palmarum* — P	Bogs	

B — Breeding W — Wintering
M — Migratory P — Possible

Birds	Literature Habitat	Planning Unit Habitat
Ovenbird *Seiurus aurocapillus* — B	Deciduous forest	
Northern Waterthrush *Seiurus noveboracenisis* — B	Bogs	
Mourning Warbler *Oporornis philadelphia* — P	Heavy underbrush	
MacGillivray's Warbler *Oporornis tolmiei* — B	Brush	
Yellowthroat *Geothlypis trichas* — B	Grassy shrubby areas	
Yellow-Breasted Chat *Icteria vicens* — B	Deciduous forest	Riparian brush
Wilson's Warbler *Wilsonia pusilla* — M	Willow thickets	Dead male found in Worland — fall
American Redstart *Setophaga ruticilla* — B	Deciduous forest	
House Sparrow *Passer domesticus* — B-W	Farms and towns	Farms and towns
Bobolink *Dolichonyx oryzivorus* — B	Hayfields	
Western Meadowlark *Sturnella neglecta* — B-W	Rangelands	Rangelands
Yellow-Headed Blackbird *Xanthocephalus xanthocephalus* — B	Marshes	Riparian habitat
Red-Winged Blackbird *Agelaius phoeniceus* — B	Marshes	Riparian habitat
Orchard Oriole *Icterus spurius* — P	Wood margins	
Baltimore Oriole *Icterus galbula* — B	Shade trees	Around trees & water
Bullock's Oriole *Icterus bullocki* — B	Shade trees	
Rusty Blackbird *Euphagus carolinus* — P	Marshes	
Brewer's Blackbird *Euphagus cyanocephalus* — B	Farmland	Agricultural areas and riparian habitat
Common Grackle *Quiscalus quiscula* — B	Farmland	Agricultural areas
Brown-Headed Cowbird *Molothrus ater* — B	Farmland	
Western Tanager *Piranga olivacea* — B	Deciduous woods	Coniferous forests and hardwoods
Rose-Breasted Grosbeak *Pheucticus ludovicianus* — B	Deciduous woods	
Black-Headed Grosbeak *Pheucticus melanocephalus* — B	Open woodlands	
Lazuli Bunting *Passerina amoena* — B	Riparian brush	
Dickcissel *Spiza americana* — B	Grain fields and weeds	

B — Breeding W — Wintering
M — Migratory P — Possible

Birds	Literature Habitat	Planning Unit Habitat
Evening Grosbeak *Hesperiphona vespertina* — B-W	Conifers	Riparian woodland; winter in Basin in large flocks
Cassin's Finch *Carpodacus cassinii* — B-W	Conifers	
House Finch *Carpoducus mexicanus* — B-W	Bottomlands and towns	
Pine Grosbeak *Pinicola enucleator* — B-W	Coniferous forest	
Grey-Crowned Rosy Finch *Leucosticte tephrocotis* — W-B	Summer in mountains; winter in desert	Winters around steep rocky hills at low elevations
Black Rosy Finch *Leucosticte atrata* — B-W	Summer in mountains winter in desert	
Brown-Capped Rosy Finch *Leucosticte australis* — P	Summer in mountains winter in desert	
Common Redpoll *Acanthis flammea* — W	Weed patches	
Pine Siskin *Spinus pinus* — B-W	Conifers	
American Goldfinch *Spinus tristis* — B-W	Weeds	
Red Crossbill *Loxia curvirostra* — B-W	Pine woods	
Green-Tailed Towhee *Chlorura chlorura* — B	Sagebrush	
Rufous-Sided Towhee *Ipilo erythrophthalmus* — B	Brush — forest edges	
Lark Bunting *Calamospiza melanocorys* — B	Prairie grasslands	Grasslands — sagebrush; arrives about May 15
Savannah Sparrow *Passerculus sandwichensis* — B	Short grass	
Grasshopper Sparrow *Ammodramus savannarum* — B	Weeds	
Baird's Sparrow *Ammodramus bairdii* — M	Weeds	
Vesper Sparrow *Pooecetes gramineus* — B	Grasslands	Common in rangeland
Lark Sparrow *Chondestes grammacus* — B	Near brush	
Black-Throated Sparrow *Amphispiza bilineata* — P	Sagebrush	
Sage Sparrow *Amphispiza belli* — B	Sagebrush	
Slate-Colored Junco *Junco hyemalis* — W	Weeds and brush	
Oregon Junco *Junco oreganus* — W	Farmyards and fields	Brushy riparian areas
Tree Sparrow *Spizella arborea* — W	Weeds and hedgerows	
Chipping Sparrow *Spizella passerina* — B	Short grass	
Clay-Colored Sparrow *Spizella pallida* — B	Open brushland	

B — Breeding W — Wintering
M — Migratory P — Possible

Birds	Literature Habitat	Planning Unit Habitat
Brewer's Sparrow *Spizella breweri* — B	Sagebrush	
Field Sparrow *Spizella pusilla* — B	Tall grass	
Harris' Sparrow *Zonotrichia querula* — W	Wood margins and brush	
White-Crowned Sparrow *Zonotrichia leucophrys* — B-W	Thickets	
White-Throated Sparrow *Zonotrichia albicollis* — M	Dense brush	
Fox Sparrow *Passerella iliaca* — B	Dense brush	
Lincoln's Sparrow *Melospiza lincolnii* — B	Thickets along streams	
Song Sparrow *Melospiza melodia* — B-W	Moist brushy areas	
McCown's Longspur *Rhyncholophanes mccownii* — B	Arid plains	
Lapland Longspur *Calcarius lapponicus* — W	With horned larks — plains	
Smith's Longspur *Calcarius pictus* — B	Short grass plains	
Chestnut-Collared Longspur *Calcarius ornatus* — B	Prairies	
Snow Bunting *Plectrophenax nivalis* — W	Short grass	

B — Breeding W — Wintering
M — Migratory P — Possible

Appendix 4

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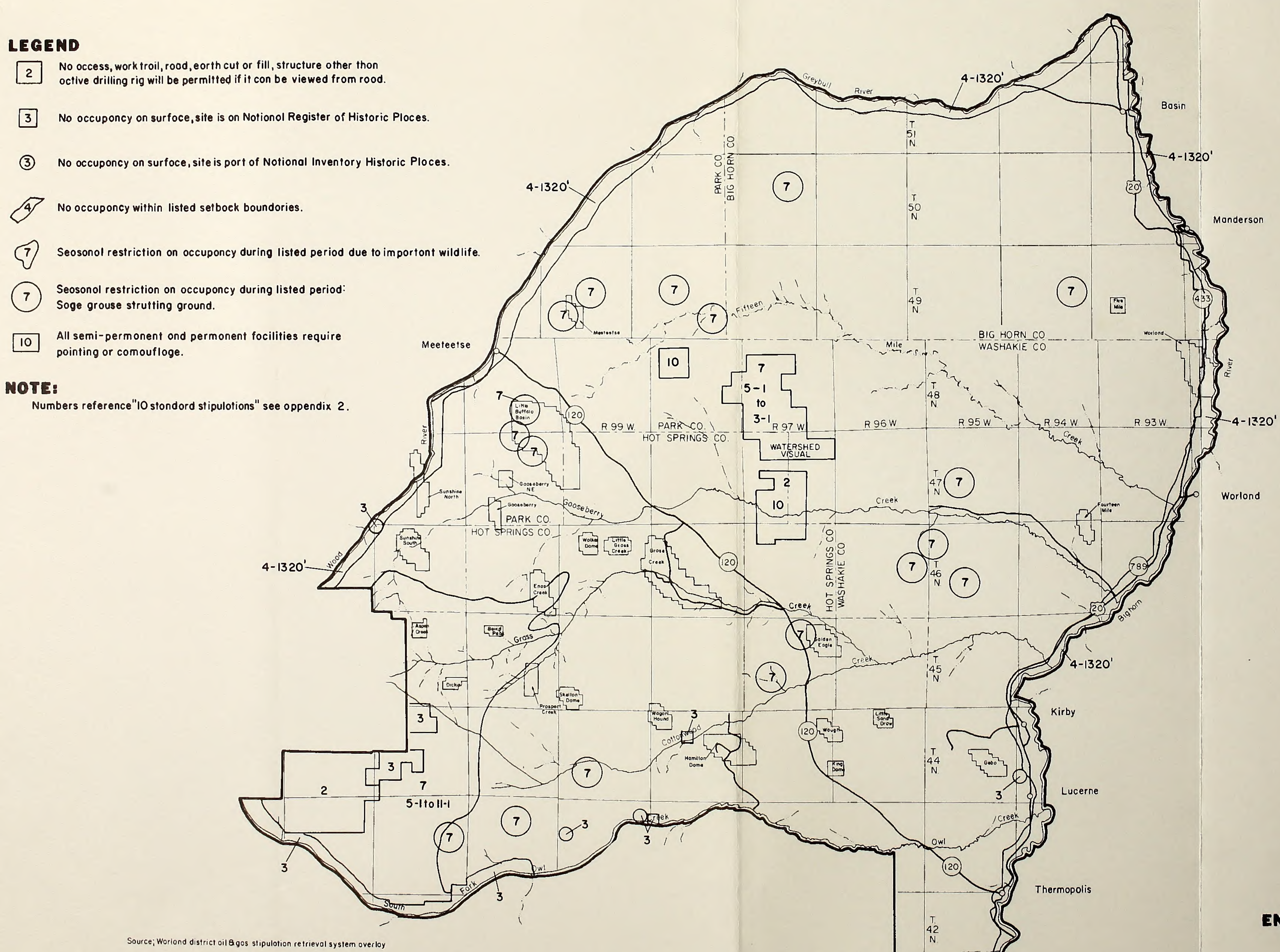
MAPS



MAP 2
OIL AND GAS LEASE STIPULATIONS
GRASS CREEK
OIL AND GAS LEASING
ENVIRONMENTAL ASSESSMENT RECORD

MAP 3
GENERAL SOIL MAP

GRASS CREEK

OIL AND GAS LEASING

ENVIRONMENTAL ASSESSMENT RECORD

LEGEND – GENERAL SOIL MAP

C - Cold Soils of the Mountains and Mountain Valleys

C2 Rough, very steep mountainous areas with fifty percent or more rock outcrop. Areas are either barren or covered with alpine vegetation. Elevation is 10,000 feet or more.

C3 Soils developing in volcanic materials in mountainous areas with many rock outcrops. Elevation ranges from 7,000 to 12,000 feet.

C4 Soils developing in granite, gneiss, and schist in mountainous areas with many rock outcrops. Elevation ranges from 7,000 to 12,000 feet.

C5 Soils developing in limestone and quartzite on rounded knolls and ridges and steep mountainous areas with many rock outcrops. Elevation ranges from 7,000 to 10,000 feet.

C6 Soils developing in sandstone and thin strata of limestone on steep, strongly dissected mountain fronts. Many rock outcrops are included. Elevation ranges from 5,500 to 7,000 feet.

F - Cool Soils of Mountain Foothills and Desertic Basins

F1 Soils developing in alluvial deposits on floodplains, stream terraces, and fans. Elevation ranges from 5,700 to 7,000 feet.

F3 Soils developing in redbeds with thin, interbedded sandstone and limestone on rolling to steep, dissected uplands. There are many rock outcrops. Elevation ranges from about 6,000 to 7,000 feet.

F4 Soils developing in interbedded sandstone and shale on strongly dissected, rolling to steep uplands with some rock outcrops. Elevation ranges from 6,000 to 7,000 feet.

M - Warm Soils of Desertic Basins

M1 Soils developing in alluvial deposits on floodplains, stream terraces, and fans. Elevation ranges from 4,000 to 5,700 feet.

M2 Soils developing in redbeds and some limestone and sandy shales on rolling to steep, strongly dissected uplands with many rock outcrops. Elevation ranges from 5,000 to 6,000 feet.

M3 Soils developing in alluvial deposits on nearly level to sloping high terraces. Elevation ranges from 4,000 to 5,500 feet.

M4 Soils developing in shale on nearly level to sloping uplands with some narrow valleys with steep side slopes. Elevation ranges from 4,000 to 6,000 feet.

M5 Soils developing in shale on strongly dissected, rolling to steep uplands with many shale outcrops. Elevation ranges from 4,000 to 6,000 feet.

M6 Soils developing in interbedded sandstone and shale on undulating to rolling uplands. Included are small areas of soils developing in alluvial deposits on remnant high terraces. Elevation ranges from 4,000 to 6,000 feet.

M7 Soils developing in interbedded sandstone and shale on strongly dissected, rolling to steep uplands with some rock outcrops. Elevation ranges from 4,000 to 6,000 feet.

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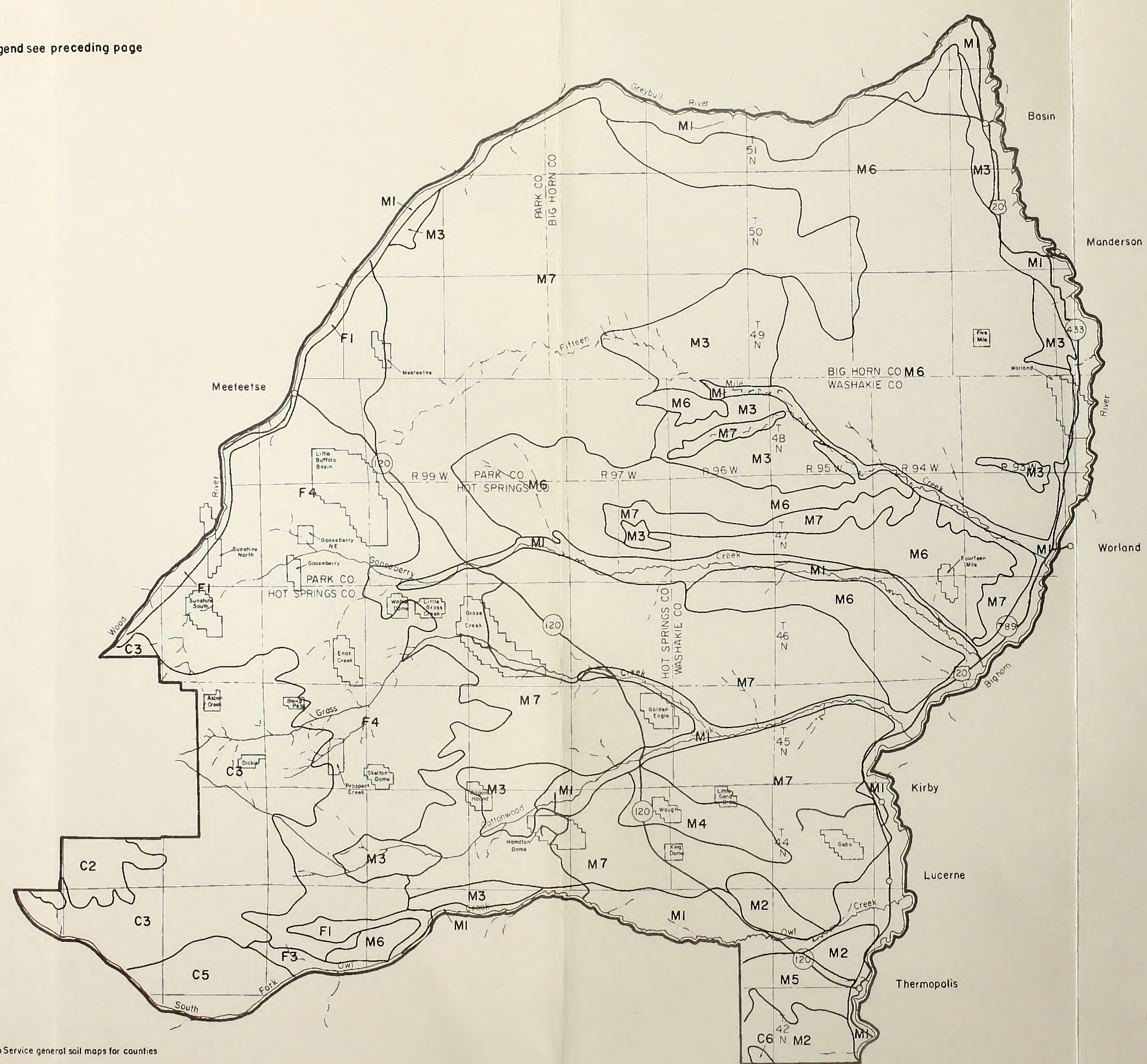
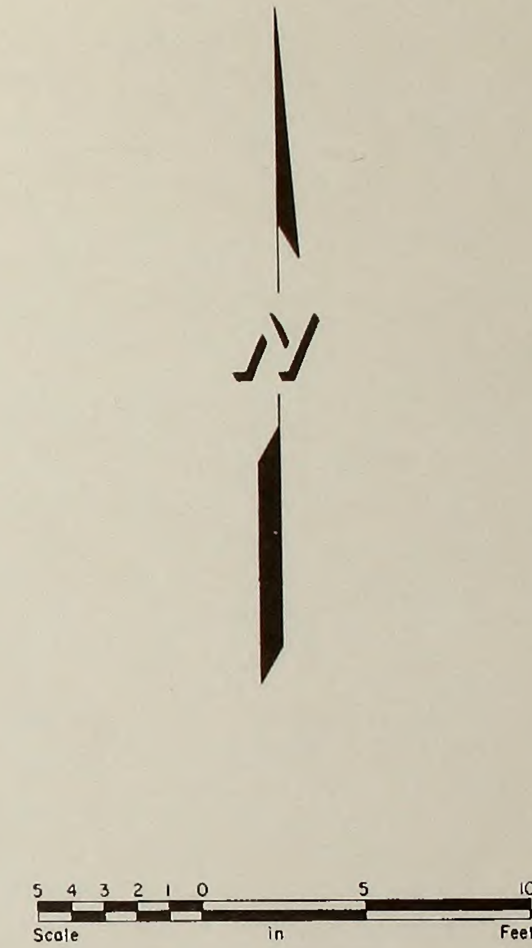
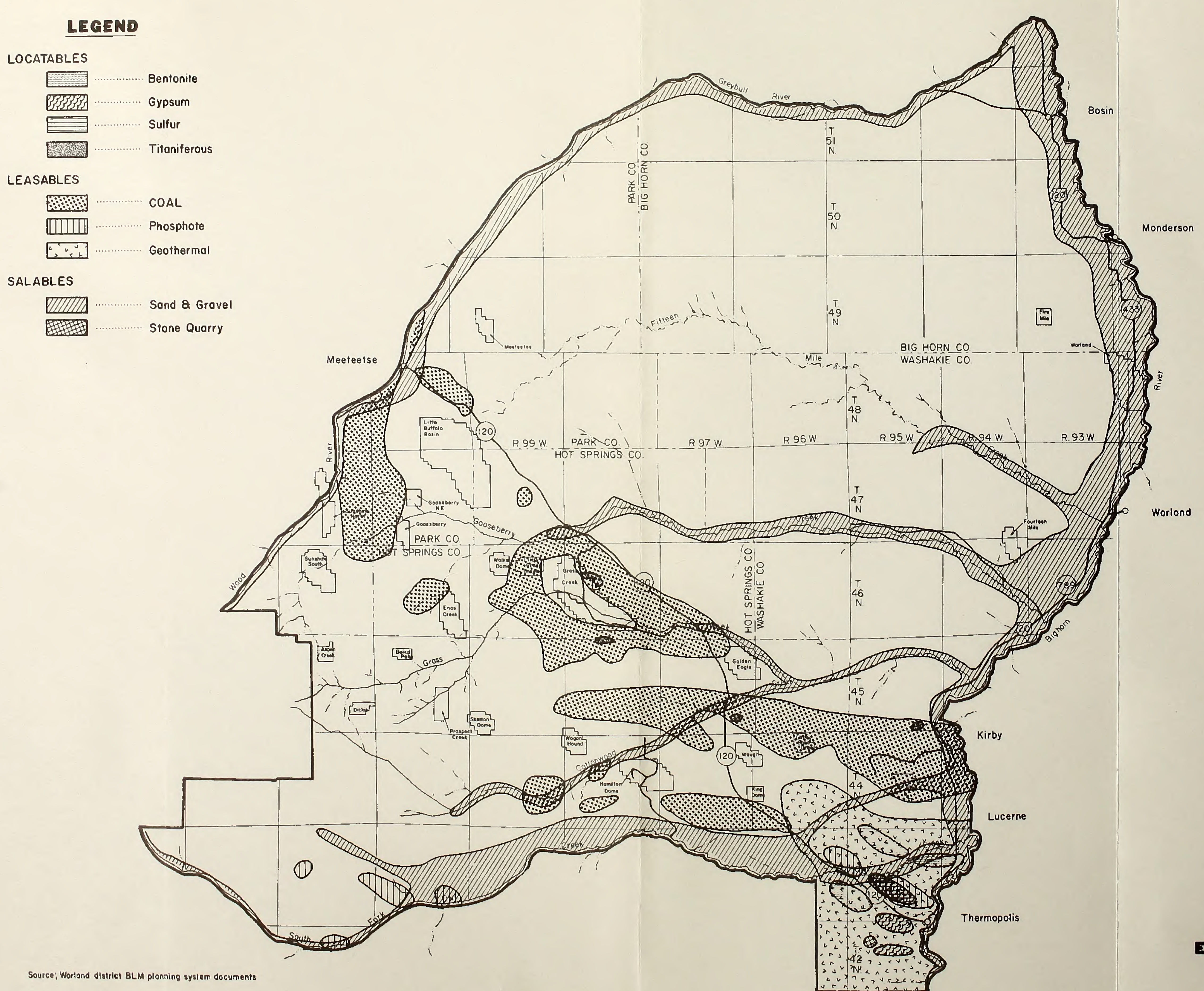




Source; Soil Conservation Service general soil maps for counties

MAP 3
GENERAL SOIL MAP

GRASS CREEK
OIL AND GAS LEASING
ENVIRONMENTAL ASSESSMENT RECORD



Source; Worland district BLM planning system documents

Scale in Feet
5 4 3 2 1 0 5 10

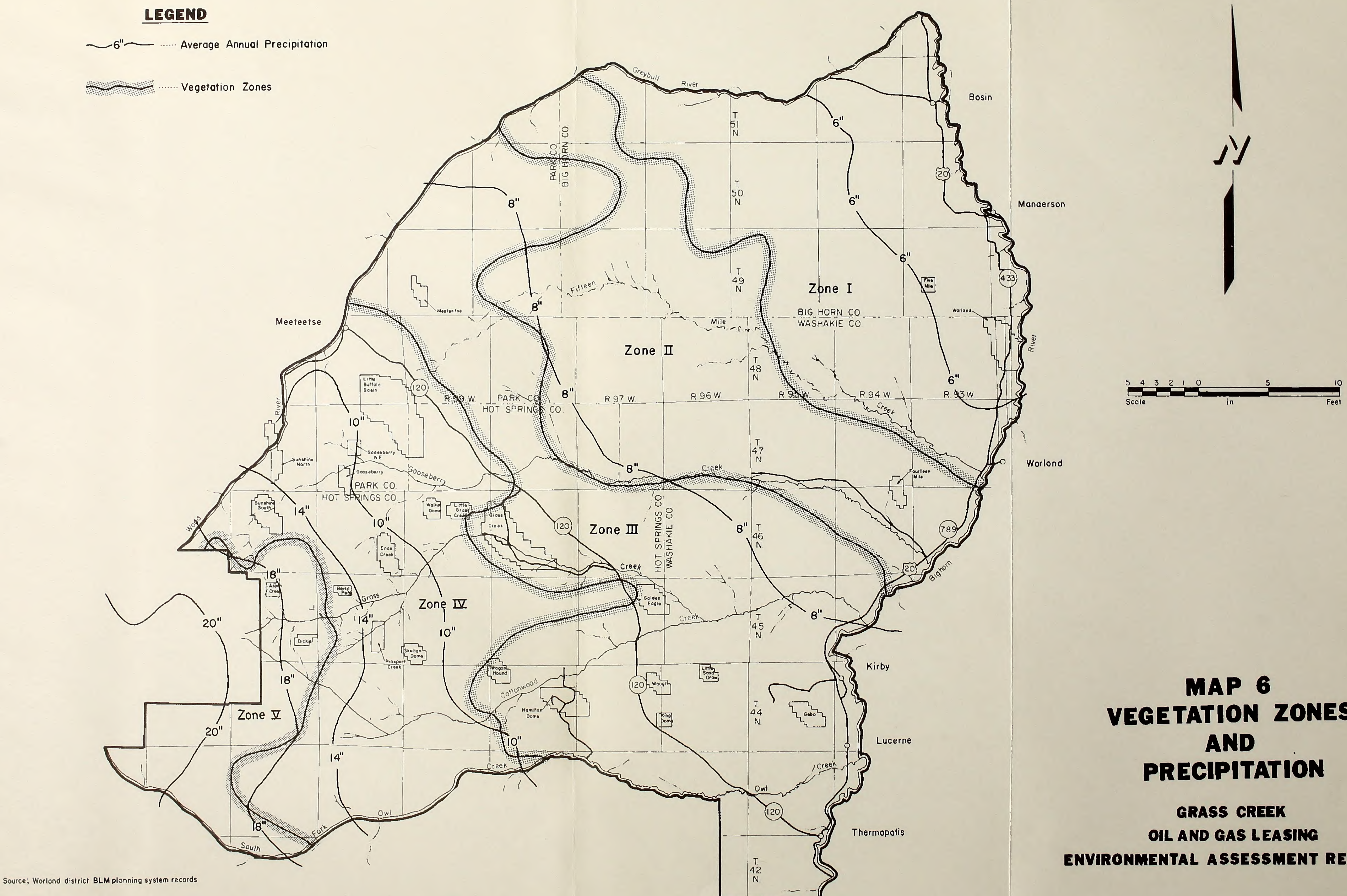
MAP 4
MINERALS

GRASS CREEK
OIL AND GAS LEASING
ENVIRONMENTAL ASSESSMENT RECORD

MAP 5
SURFACE WATER AND SAMPLING STATIONS

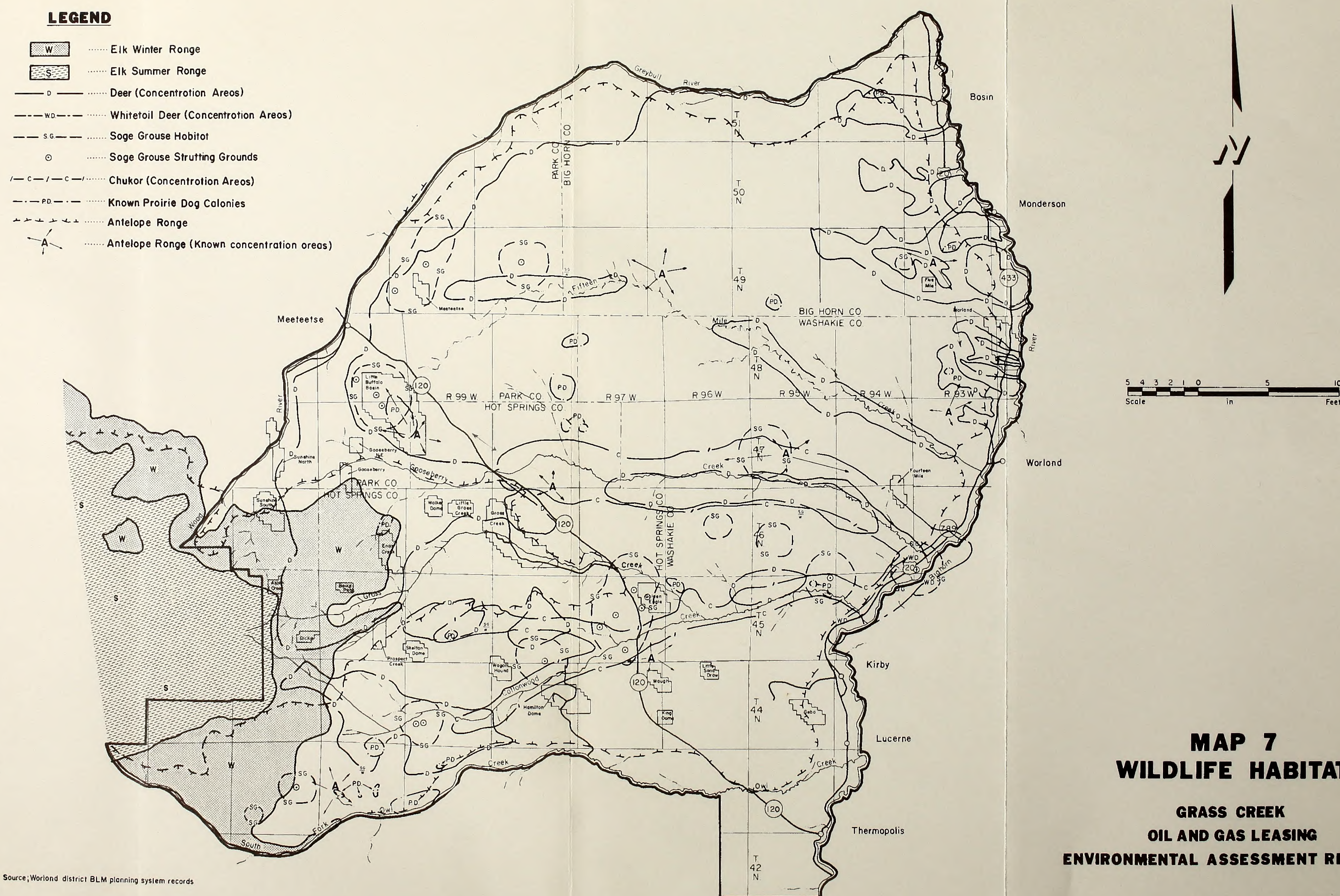
GRASS CREEK
OIL AND GAS LEASING
ENVIRONMENTAL ASSESSMENT RECORD

Source; Worland district BLM planning system records.



MAP 6
VEGETATION ZONES AND PRECIPITATION

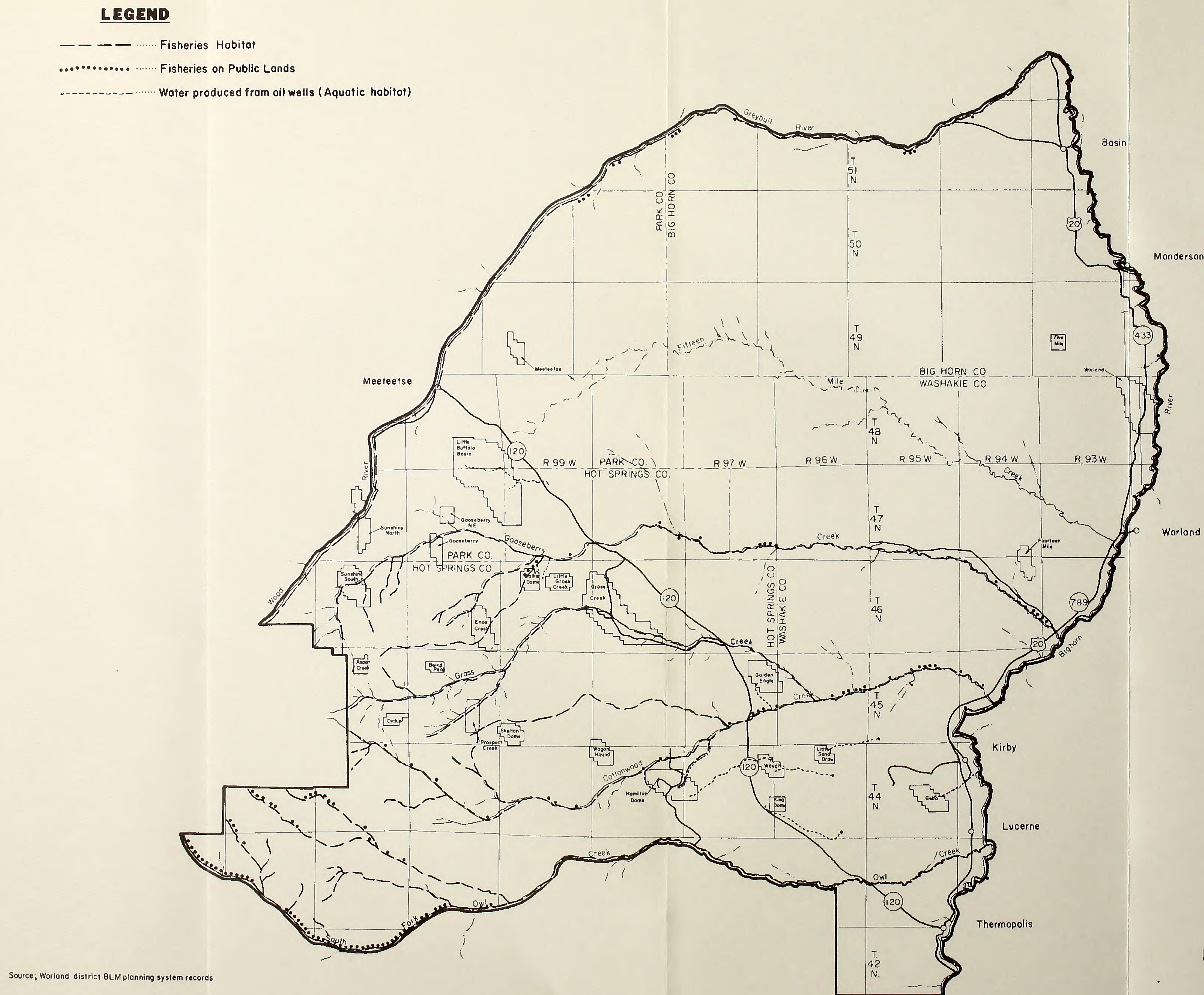
GRASS CREEK
OIL AND GAS LEASING
ENVIRONMENTAL ASSESSMENT RECORD



MAP 7
WILDLIFE HABITAT

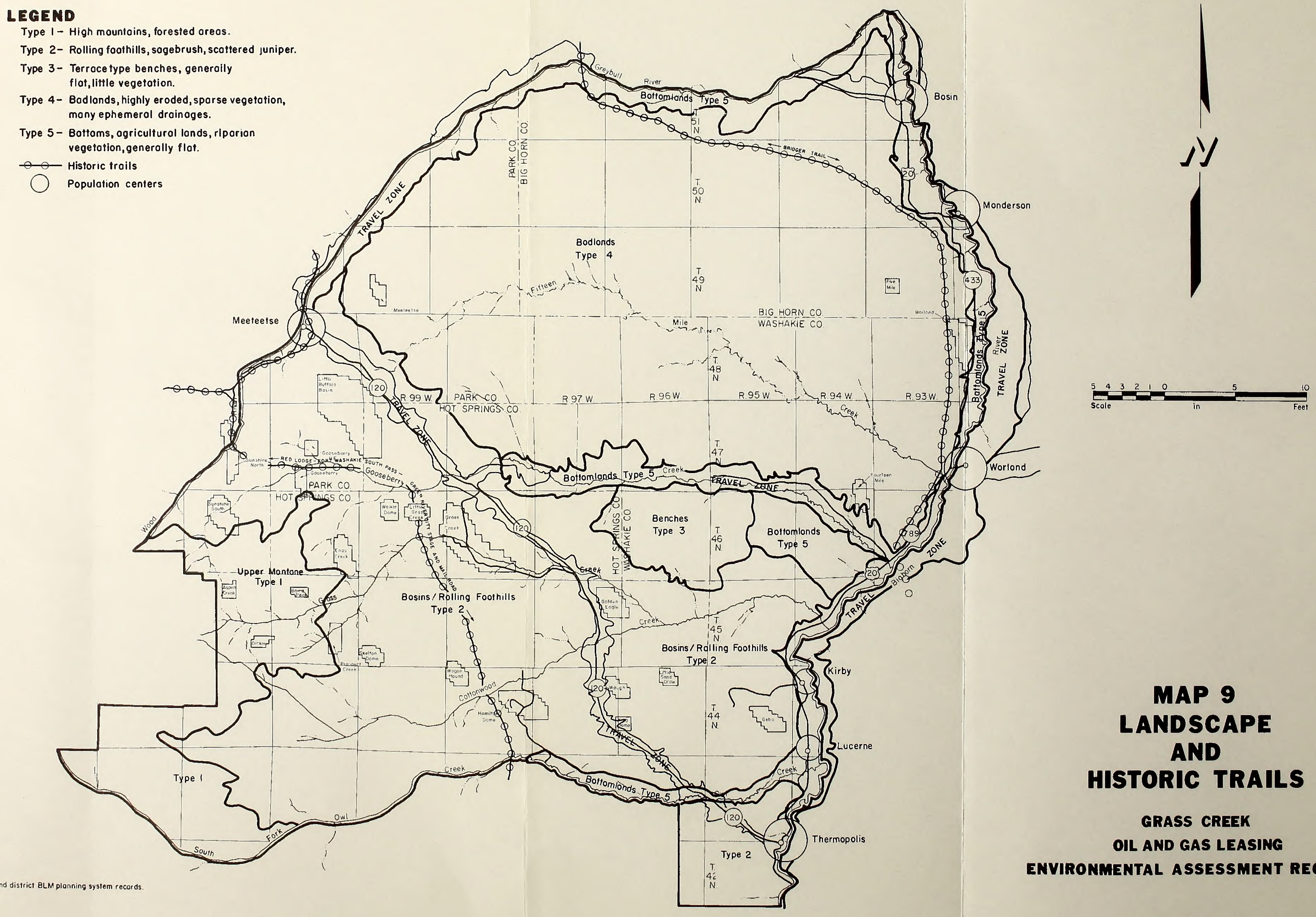
GRASS CREEK
OIL AND GAS LEASING
ENVIRONMENTAL ASSESSMENT RECORD

Source; Worlond district BLM plonning system records



MAP 8
FISHERIES

GRASS CREEK
OIL AND GAS LEASING
ENVIRONMENTAL ASSESSMENT RECORD



MAP 9
LANDSCAPE AND HISTORIC TRAILS

GRASS CREEK
OIL AND GAS LEASING
ENVIRONMENTAL ASSESSMENT RECORD